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# THE IMPACT OF QUALITY INFRASTRUCTURE ON GLOBAL VALUE CHAIN PARTICIPATION

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACFTA | African Continental Free Trade Agreement |
| AfCFTA | African Continental Free Trade Area |
| BIPM | International Bureau of Weights and Measures |
| CVC | Coffee Value Chain |
| EU | European Union |
| FDI | Foreign Direct Investment |
| GDP | Gross Domestic Product |
| GQII | Global Quality Infrastructure Index |
| GVC | Global Value Chain |
| IAF | International Accreditation Forum |
| IAF MRA | Mutual Recognition Arrangement of the International Accreditation Forum |
| IEC | International Electrotechnical Commission |
| ILAC | International Laboratory Accreditation Forum |
| INetQI | International Network on Quality Infrastructure |
| ISO | International Organization for Standardization |
| IV | Instrumental Variable |
| LS-BE | Least Squares Between Effects |
| MLA | Multilateral Recognition Arrangement |
| MRA | Mutual Recognition Arrangement |
| MSME | Micro, Small and Medium Enterprises |
| NQI | National Quality Infrastructure |
| OECD | Organisation for Economic Co-operation and Development |
| PAQI | Pan African Quality Infrastructure |
| PTA | Preferential Trade Arrangement |
| QI | Quality Infrastructure |
| QI4SD | Quality Infrastructure for Sustainable Development |
| QIS | Quality Infrastructure System |
| RoW | Rest of the World |
| SDGs | Sustainable Development Goals |
| SME | Small and Medium Enterprises |
| SPS | Sanitary and Phytosanitary |
| TiVA | Trade in Value Added |
| UNCTAD | United Nations Conference on Trade and Development |
| UNIDO | United Nations Industrial Development Organization |
| US | United States |
| WDI | World Development Indicators |
| WTO | World Trade Organization |
| WVC | Wheat Value Chain |

# FOREWARD

Sustainable development involves the strengthening of local firms. The continuous improvement in processes, products and functions to increase value added, that the literature and the policy practice have called firms' upgrading, is absolutely essential for emerging economies to compete sustainably in global markets. This is true for developing countries in Africa as well as for countries trapped at lagging levels of middle-income. In turn, upgrading requires Quality Infrastructure (QI), the ecosystem of public and private institutions that generate and diffuse the experiential, applied knowledge that helps domestic firms transform their capabilities to meet international process and product standards in an economically sustainable manner.

This thesis represents an admirable effort to improve our understanding of what effective QI ecosystems are, and how they influence countries' participation in Global Value Chains. It opens the door to new and relevant questions on how and why these institutions are created, how they interact with industrial and innovation policies, why they differ across countries and whether such differences matter for firms' and industries' upgrading. New studies will deal with these questions, in an overly due debate that this thesis contributes to launch. This will help inform and deepen our understanding of the role that institutions play in the development process.

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# ABSTRACT

This working paper uses a country-level approach to investigate whether Quality Infrastructure (QI) has any impact on Global Value Chain (GVC) participation, particularly for African countries, from 2010 to 2020. We hypothesize that QI positively affects GVC involvement and that it is therefore important for countries, especially in Africa, to further develop their QI ecosystems to become more integrated into GVCs. The country-level analysis relies on decadal averages and a Least Squares Between Effects estimation strategy and covers 103 countries, 29 of which are in Africa. The results indicate that QI plays a significant role in GVC participation, with the positive effects being driven by standardization and metrology. As such, all countries seeking to become embedded in GVCs should invest in developing their QI ecosystems.

# 1 INTRODUCTION

Global Value Chains (GVCs) refer to the fragmentation of the production of a product or service into a series of stages, where value is added in each stage, and at least two of the stages take place in different countries before reaching the final customer (Allard et al., 2016; Raei et al., 2019; World Bank, 2020). Depending on the nature of the product or service, GVCs may be simple and follow a linear arrangement involving few firms and few border crossings; or they may be arranged into complex global production networks with multiple border crossings and several firms collaborating to complete each stage (Gereffi & Fernandez-Stark, 2016; World Bank & IBRD, 2017).

The emergence of GVCs has allowed countries to take advantage of their comparative advantages without performing all of the required processes before the product reaches the final production stage (Allard et al., 2016). Therefore countries can specialise in specific production areas and join supply chains (Allard et al., 2016).

Despite existing for centuries, GVCs rose to prominence in the 1990s when they began to grow rapidly due to lower trade barriers and technological advances in transportation, information and communications. Since then, they have brought revolutionary changes to international trade, economic development and industrialisation, which have contributed to higher levels of growth and productivity, steep declines in poverty, more employment opportunities and higher incomes in countries that have become integrated into GVCs. Even though the expansion of GVC trade has slowed since the 2008 financial crisis; and is being challenged by trade conflicts between large countries, labour-saving technologies and reshoring; it still accounts for about 70% of the international trade (OECD, n.d.).

Significant gains can be achieved at any stage of a GVC. Countries can expect at least a 1% increase in per capita income by increasing their GVC participation by 1%, which is significantly higher compared to the 0.2% income gain they can expect from increasing their participation in standard trade by 1% (World Bank, 2020). Upstream activities, or forward GVC participation, tend to be associated with lower gains. Therefore once countries become integrated into value chains, they usually aim to move up to higher value-added, more skillintensive activities (Del Prete et al., 2018; WTO, 2019). Countries typically experience the biggest increase in per capita income when they transition out of exporting commodities and begin exporting basic manufactured products (World Bank, 2020).

Over the years, numerous studies have been done on GVCs to understand the main determinants of participation and ways to improve embeddedness. Factors such as natural resource endowment, labour supply, Foreign Direct Investment (FDI) inflows, geography, trade openness, political stability, and physical infrastructure (transportation, communication, energy, water) were analysed and found to contribute to GVC engagement to varying extents depending on the country, region and the type of GVC activity. However, none of these studies considered the impact of Quality Infrastructure (QI).

QI refers to the entire system of policy, legal, regulatory and administrative frameworks, as well as the institutional arrangements needed to provide standardization, metrology, accreditation and conformity assessment services (Kellermann & Keller, 2015). QI services play a crucial role in GVCs as they ensure and provide evidence that the in-country part of production is seamlessly aligned with the global production chain (Kellermann & Keller, 2015). Without proof of quality, it is challenging to enter international markets as countries have imposed technical regulations to protect consumers and the environment from substandard products. It is even more challenging to become embedded in GVCs as a high level of trust and collaboration is required among participants since delays or lack of compliance with specific requirements could result in significant losses.

While the importance of QI in GVC participation has been mentioned in a few studies, and some studies have provided empirical evidence that various QI elements facilitate international trade, until now, there has not been an empirical assessment of the impact of QI on GVC involvement. There are several possible reasons for the lack of research in this area. Firstly, awareness and understanding of QI have not yet expanded beyond QI expert circles (Harmes-Liedtke & Oteiza, 2021b). This is because most QI-related work takes place in the background; once the system operates smoothly, it usually goes unnoticed (Brown, 2021). Secondly, until 2020, when the Global Quality Infrastructure Index (GQII) was introduced, no indicators provided a measure of overall QI development on a global scale. This working paper attempts to draw attention to this gap in the literature and contribute to the initial discussion and findings.

More specifically, this working paper aims to establish a link between QI and GVC participation, particularly for African countries, from 2010-2020. It tries to answer the questions, "Does QI have an impact on GVC participation?" and "Is it necessary for African countries to develop their QI ecosystems to become more integrated into GVCs?". It attempts to test the hypothesis that QI makes a positive contribution to GVC integration by using country-level data to investigate the impact of a country's level of National Quality Infrastructure (NQI) development on its GVC participation. This provides insight into whether having a robust NQI that can competently provide the QI services in demand affects a country's GVC involvement. This is initially analysed globally and then narrows the focus to African countries. It is critical to focus on Africa since the continent has been slowly trailing behind the Rest of the World (RoW) regarding GVC participation and QI development. As a result, most African countries have not been able to capitalise on the gains associated with GVC trade. Understanding how QI affects GVC trade could provide some critical insight into why Africa has not yet been able to become as embedded in GVCs as many other developing countries around the world have and whether investing in QI could be a step towards catching up to the RoW.

This working paper is organised as follows. Chapter 2 discusses the link between QI and GVCs. Chapter 3 compares Africa's GVC participation and level of QI development with the RoW. A detailed literature review is presented in Chapter 4. Chapter 5 presents the country-level analysis, and Chapter 6 concludes. Supplementary information to support this working paper is available in the appendices.

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# QUALITY INFRASTRUCTURE AND GLOBAL VALUE CHAINS

In 2017, members of the International Network on Quality Infrastructure[1] (INetQI) defined QI as "the system comprising the organizations (public and private) together with the policies, relevant legal and regulatory framework, and practices needed to support and enhance the quality, safety and environmental soundness of goods, services and processes" (INetQI, 2022c). This comprehensive system, illustrated in Figure 1, is required to establish and implement metrology (scientific, industrial and legal), standardization, accreditation, conformity assessment (inspection, testing and product- and system certification), market surveillance and quality promotion services (INetQI, 2022c; Kellermann & Keller, 2015).

These services are necessary to prove that products and services meet the requirements specified by authorities (for instance, in the case of technical regulations) or the marketplace (either contractually or inferred) (Kellermann & Keller, 2015). A well-functioning Quality Infrastructure System (QIS) equips companies with the necessary knowledge and tools to meet international standards, facilitating their access to foreign markets (UNIDO, 2016). It leads to more opportunities to export and diversify products, attract investments, become embedded in global value chains, and earn foreign currency. As production has become increasingly fragmented across countries, and producers and manufacturers have become tightly integrated into GVCs, the demand for quality has increased as well (Guasch et al., 2007; Tippmann, 2013). QI plays a crucial role in each link of a GVC; therefore, countries depend heavily on their QI ecosystems to remain competitive in the worldwide economy (Guasch et al., 2007; Wipplinger et al., 2006). In other words, countries need robust QI systems to enter and improve their positions in GVCs (Gonçalves & Peuckert, 2011; Guasch et al., 2007; Kellermann & Keller, 2015; Tippmann, 2013; UNIDO, 2011; Wipplinger et al., 2006).

QI facilitates GVC participation in numerous ways, with each QI component playing a distinct role. Standards and technical regulations ensure compatibility between products and processes in GVCs (Guasch et al., 2007). They specify the product and process requirements that producers and manufacturers must comply with to satisfy customers, many

*[1] The INetQI is a consortium that actively promotes and implements activities in standardization, accreditation, metrology and conformity assessment as facilitators of sustainable economic development (INetQI, 2022a). The following specialized international organizations comprise the INetQI: the International Bureau of Weights and Measures (BIPM), the International Accreditation Forum (IAF), the International Electrotechnical Commission (IEC), the Independent International Organisation for Certification (IIOC), the International Laboratory Accreditation Cooperation (ILAC), the IQNET Association, International Organisation for Standardisation (ISO), the International Trade Centre (ITC), the International Telecommunication Union (ITU), the International Organization of Legal Metrology, the United Nations Economic Commission for Europe (UNECE), the United Nations International Development Organisation (UNIDO), the World Bank Group (WBG), and the World Trade Organization (WTO) (INetQI, 2022b).*

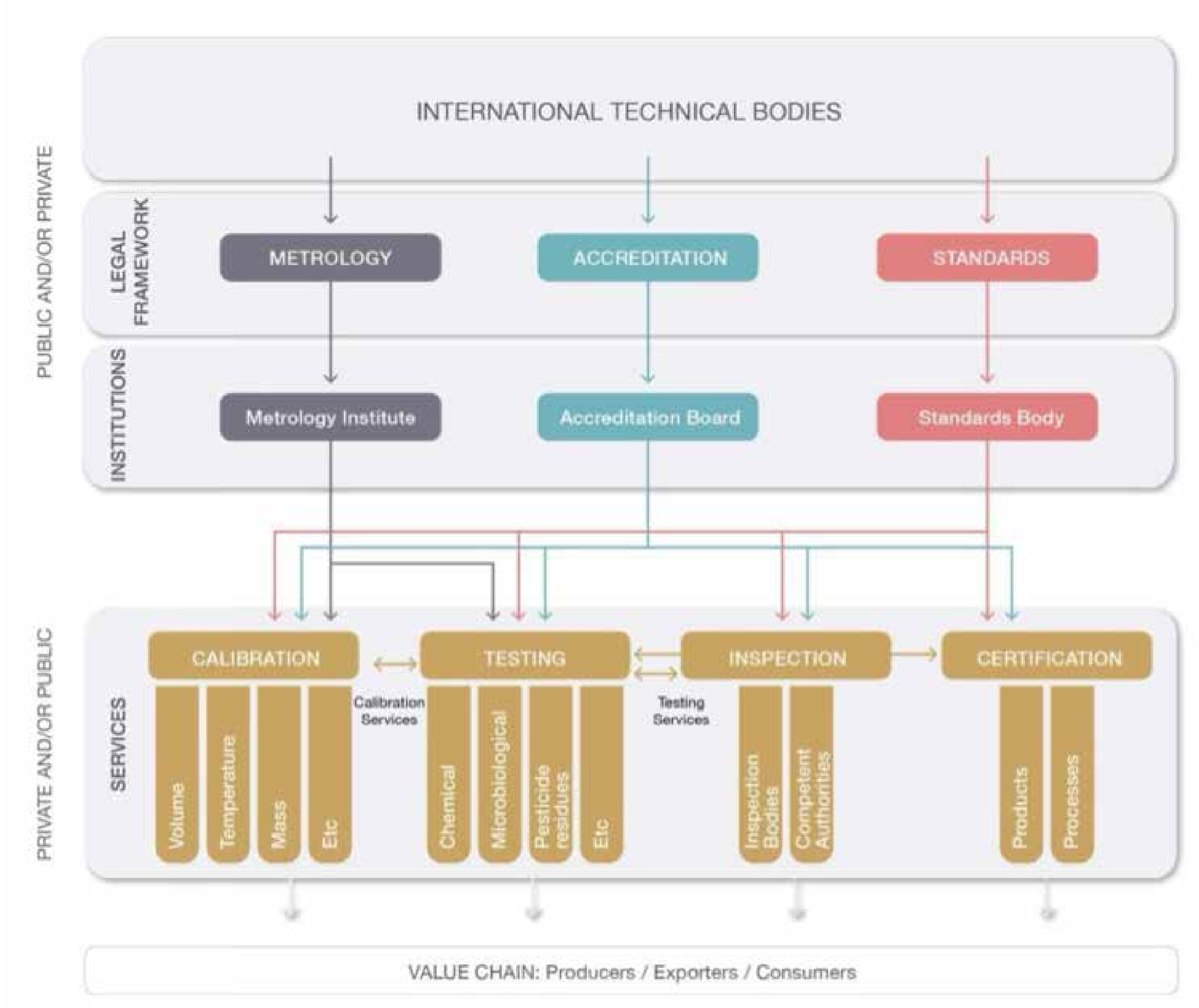



Figure 1: A complete QI ecosystem with all the necessary institutions and their interrelations
Source: Kellermann and Keller (2015, p. 14)

of which are firms themselves that purchase intermediate products to be used as inputs in their own production processes. Metrology services are needed to ensure that properly calibrated equipment and internationally accepted units of measurement are being used throughout the process. Conformity assessment services are required to demonstrate that products meet the specific requirements defined in standards and technical regulations. Accreditation is needed to show that service providers are competent to carry out their particular tasks. Market surveillance is required to ensure that only quality products are placed on the market.

Long value chains with many partners require high levels of coordination and trust as the next stage of the value chain depends on the outcomes of the stage before (Gonçalves & Peuckert, 2011). QI builds trust among partners by providing the tools required for stable outcomes in each value chain stage. Higher confidence levels could lead to opportunities to work with new partners and enter new markets (Gonçalves & Peuckert, 2011). Additionally, the demand for QI grows when more complex goods are exchanged along value chains as the codification of product characteristics and the requirement to demonstrate compliance increase to ensure that outcomes in one stage of the chain are fit for use in the next stage. QI helps minimise the risks associated with producing complex goods, such as automobiles, which depend on parts and components produced in different countries and assembled in one location (Taglioni & Winkler, 2016).

QI increases GVC integration by increasing economic efficiency along the chain. It lessens asymmetric information between buyers and suppliers concerning quality, safety, the production process and specific product characteristics (Beghin et al., 2015; UNIDO, 2011). Furthermore, it lowers search costs. Standards, technical regulations and conformity assessment significantly reduce the effort required to find a product that complies with a specific set of characteristics or production process (Gonçalves & Peuckert, 2011). Additionally, it stimulates economies of scale by setting specific characteristics for products. This means that producers can produce a homogenous good instead of a specific good for each buyer, thereby lowering the per-unit cost of production. QI also reduces transaction costs. For instance, the need for customers to double-check whether a product conforms to a specific set of requirements decreases if the supplier can demonstrate compliance with certification from an accredited institution (Gonçalves & Peuckert, 2011). In addition, QI reduces adverse selection since producers can use the conformity assessment framework to differentiate their products concerning quality (Gonçalves & Peuckert, 2011).

The importance of QI in GVCs is illustrated in Figure 10 and Figure 11 in Appendix A, which highlight the QI requirements from the beginning to the end of a mango Value Chain (VC) and a wheat VC respectively.

# 3 AFRICA COMPARED TO THE REST OF THE WORLD

## 3.1. GLOBAL VALUE CHAIN PARTICIPATION

Even though Africa's economic performance has improved over the last decade, many African countries still generally find themselves at the start of their integration into GVCs (Allard et al., 2016; Conde et al., 2015). As a result, Africa's performance in GVC trade is significantly lower than the Rest of the World (RoW). On average, GVC participation accounted for only 8% of the Gross Domestic Product (GDP) in African countries between 2000 and 2015, notably lower compared to the 11% in Asian countries and 14% in high-income countries (Siba, 2022). Furthermore, GVC participation among African countries is uneven, with North and Southern Africa driving the continent's involvement in GVC trade (Conde et al., 2015). With the exception of some African countries, like Morocco, Tunisia, Tanzania, South Africa, Kenya, Namibia and Ethiopia, that have become embedded in manufacturing GVCs, the majority of the continent's GVC participation is centred around upstream activities. Most countries specialise in supplying raw materials, or lightly manufactured intermediates, to countries involved in tasks at the higher end of the GVC (Hartwich & Hammer, 2021; Siba, 2022; World Bank, 2020).

Figure 2 presents Africa's backward and forward GVC participation across three decades, from 1990 to 2020, compared to the RoW. Despite small increments in each decade, Africa lags behind the RoW in both backward and forward GVC participation. In addition, while the RoW has a higher share of backward GVC participation compared to forward GVC participation, this is the opposite in Africa, where forward GVC participation shares are higher than backward GVC participation shares.

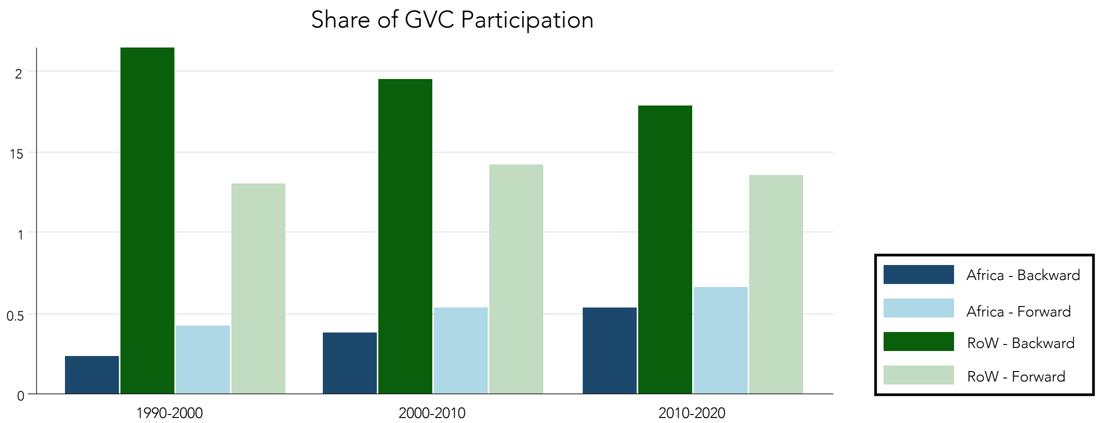


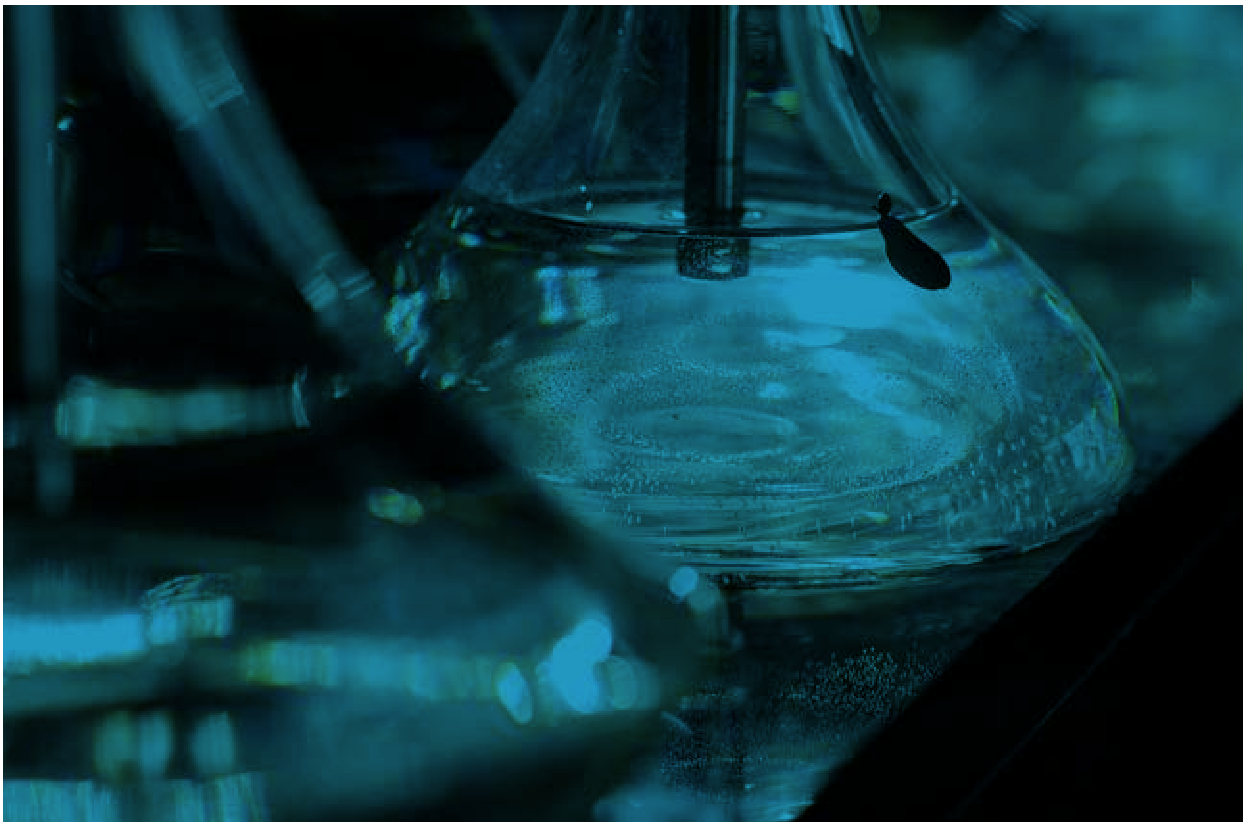

*Figure 2: Africa's GVC participation compared to the rest of the world*
*Source: Own elaboration using data from the Eora database provided by Fernandes et al. (2020)*

Hartwich and Hammer (2021) highlight several challenges that explain Africa's weak GVC integration. Some of them include high tariffs and non-tariff barriers, inconsistent trade policies, limited exploitation of markets, weak linkages between primary producers and industries and markets, poor quality culture, poor digital connectivity in some parts of the African business environment, weak physical infrastructure development and inadequate support for Small and Medium Enterprise (SME) development.

While Africa has been trying to address some of these issues to catch up to the RoW in terms of GVC involvement, the RoW's GVC participation has either stagnated or declined slightly. GVC expansion has slowed since the financial crisis of 2008 due to a decrease in overall economic growth and investment, crises in the multilateral trading system, countries developing their industrial capacities to produce intermediate inputs domestically and labour-saving technologies that reduce the need for countries to outsource labour-intensive production to countries with a large workforce (Antràs, 2020; Fernandes et al., 2020; World Bank, 2020).

Nevertheless, Africa currently has a unique opportunity to become more embedded in GVCs. Muradov (2017) found that GVCs are equilibrium systems where country positions are not independent from each other. Therefore, if one country upgrades its position, it will most likely cause a downgrade in the positions of other countries (Muradov, 2017). As Asian countries continue to upgrade their positions in GVCs and wages in these countries increase, some stages of GVCs are migrating to other countries. According to some estimates, over the next twenty years about 85 million manufacturing jobs will migrate from coastal China (Lin (2011) found in Farole (2016)). This provides opportunities for African countries to take the position of Asian counties in GVCs and become hubs of labour-intensive production, especially since Africa has a substantial working-age population, which is expected to increase by 910 million between 2010 and 2050 (Conde et al., 2015; Del Prete et al., 2018).

Furthermore, in 2019 the African Continental Free Trade Agreement (ACFTA) entered into force, establishing the African Continental Free Trade Area (AfCFTA) to boost African trade (PAQI, 2020). Until today 54 out of the 55 countries have signed the Agreement, with Eritrea being the only exception (AfCFTA, 2022). The AfCFTA is the largest free trade area in the world and supports an internal market of US$ 3 trillion with 1.2 billion consumers (AfCFTA, 2022; Hartwich & Hammer, 2021). The ACFTA is expected to eliminate unnecessary trade barriers and attract the FDI needed to boost regional processing capabilities and become embedded in regional and global value chains (AfCFTA, 2022; Siba, 2022). According to Farole (2016) the ACFTA is very promising and could facilitate the emergence of Factory Africa.



## 3.2. QUALITY INFRASTRUCTURE DEVELOPMENT

Africa lags behind the RoW concerning QI development, with only a handful of countries on the continent meeting the international average. This is according to data from the GQII, a composite indicator measuring the level of QI development across countries worldwide (Harmes-Liedtke & Oteiza, 2021b). An overview of the relative level of QI development across the 184 countries covered by the GQII is presented in Figure 3, where the development level corresponds to a colour scale from dark blue (highly developed) to dark orange (less developed) (Harmes-Liedtke & Oteiza, 2021b). Most African countries are shades of orange, indicating lower levels of QI development. Furthermore, Africa contains the highest number of orange countries, making it the least developed continent in the world concerning QI.

**Quality Infrastructure World Overview: GQII 2021 over 184 economies**

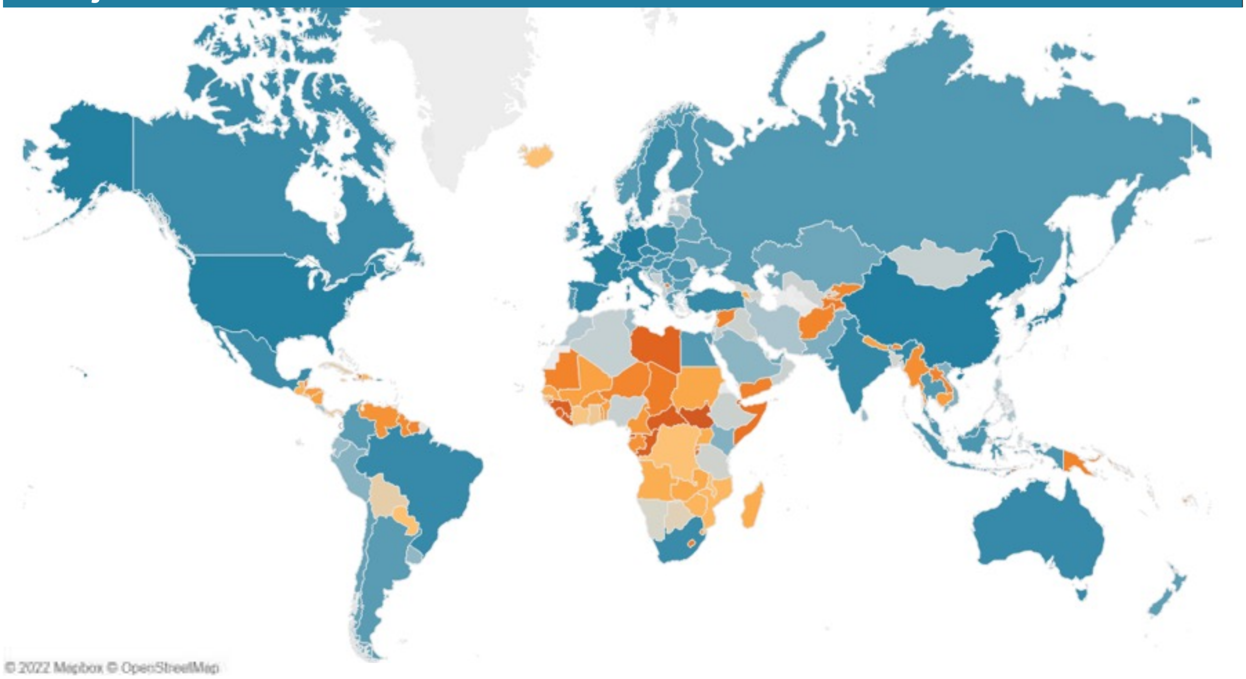
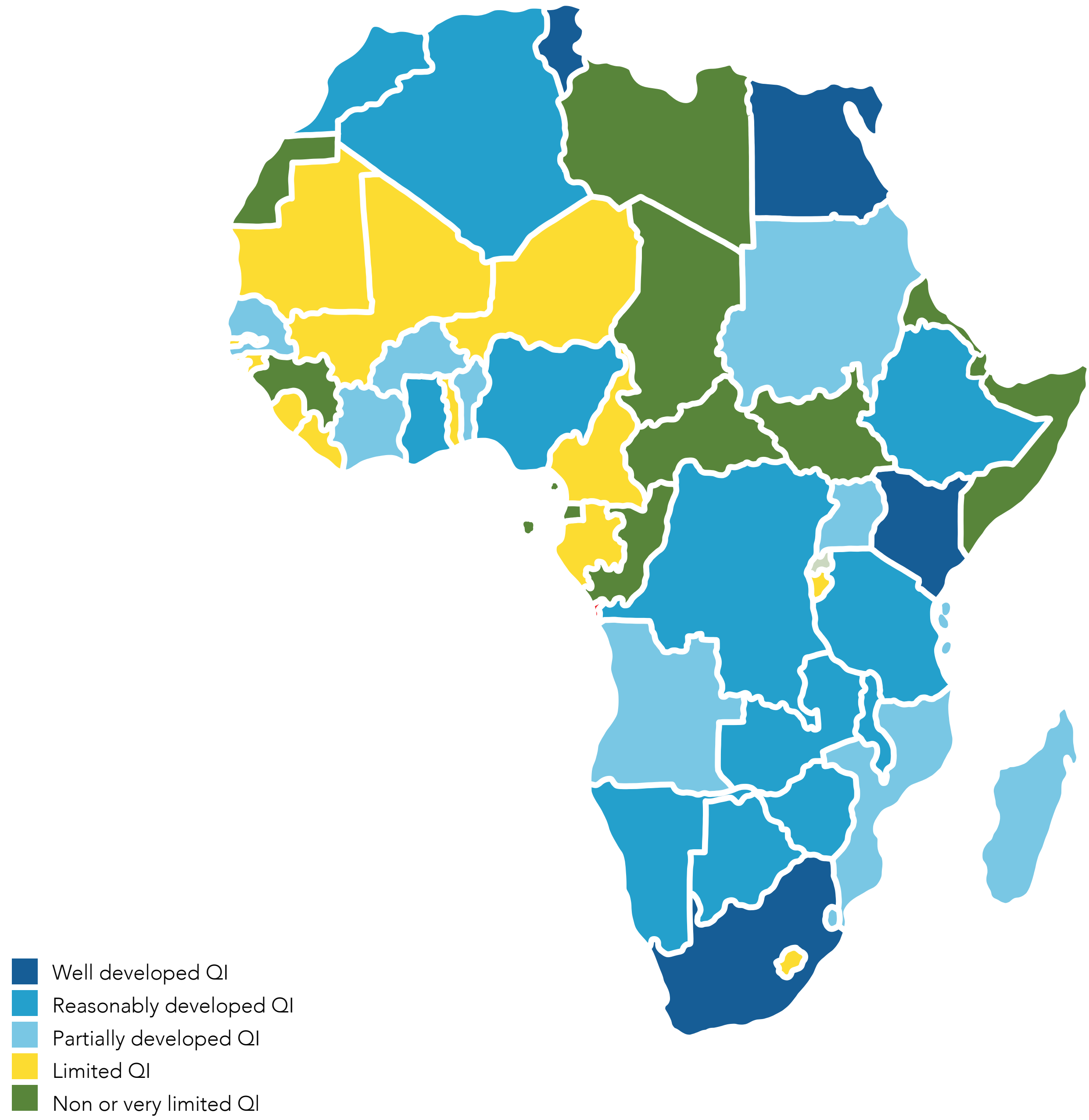



Figure 3: World overview of QI development
Legend: Dark blue (highly developed) – dark orange (less developed)
Source: GQII (2021)

There is also a significant disparity within Africa concerning QI development. According to the Pan African Quality Infrastructure (PAQI) index for 2020, only 7.3% of the continent has well-developed QISs, about 25% have reasonably developed QISs, 20% have partially developed QISs, and about 47% have little or no QI capabilities. An overview of QI development in Africa is illustrated in Figure 4.




| Category | Weight Score | Score Range | Countries |
|---|---|---|---|
| Well developed | 4 | 3.3-4.0 | Egypt, Kenya, South Africa, Tunisia |
| Reasonably developed | 3 | 2.5-3.2 | Algeria, Botswana, Democratic Republic of the Congo Ethiopia, Ghana, Malawi, Mauritius, Morocco, Namibia, Nigeria, Seychelles, Tanzania, Zambia, Zimbabwe |
| Partially developed | 2 | 1.7-2.4 | Angola, Benin, Burkina Faso, Cote d'Ivoire, Eswatini, Madagascar, Mozambique, Rwanda, Senegal, Sudan, Uganda |
| Limited | 1 | 0.9-1.6 | Burundi, Cameroon, Comoros, Gabon, Gambia, Guinea Bissau, Lesotho, Liberia, Mali Mauritania, Niger, Sierra Leone, Togo |
| Non or very little | 0 | 0-0.8 | Cape Verde Islands, Central African Republic, Chad Repulic, Congo, Djibouti, Equatorial Guinea, Eritrea, Guinea, Libya, Sahrawi Republic, Sao Tome and Principe, Somalia, South Sudan |
| Not category | | | |

The highest average - 4, the lowest average - 0

Figure 4: QI development in Africa
Source: PAQI (2020)

# 4 LITERATURE REVIEW

At the time of writing, very few studies could be found covering this specific research area. Nevertheless, this working paper can be linked to two strands of existing literature – (1) QI as a facilitator of international trade and (2) underdeveloped QI as a hindrance to international trade. A review of the relevant studies, which set the stage for the analysis, is presented below.

## 4.1. QI AS A FACILITATOR OF INTERNATIONAL TRADE

Moenius (2004) investigated the veracity of the theoretical claims that country-specific standards inhibit trade and shared standards promote trade using the gravity model. For his analysis he constructed a panel data set with country-specific and bilaterally shared standards for 471 industries in 12 countries for the period 1980-1995. His results confirmed the theoretical claims that shared standards promote trade (Moenius, 2004). However, his findings revealed that country-specific (non-shared) standards also promote trade on average, contrary to the theoretical claims (Moenius, 2004). Based on these findings he proposed that standards, both shared and country-specific, reduce information gathering costs and enable easier contracting, which is particularly useful if goods have to be adapted to suit tastes in foreign markets (Moenius, 2004). He purports that this outweighs the costs of adapting to these country-specific standards, which explains their trade promoting effects.

Swann (2010) reviewed a body of empirical work with the aim of determining the effects of international standards on international trade. His paper focused solely on empirical studies, thereby excluding papers that rely heavily on theoretical assumptions, since his aim was to learn how international standards related to trade from empirical data. His analysis revealed several conclusions: (1) in most cases exporting countries that adopt international standards experience positive (or at least neutral) effects on their export performance; (2) when exporters from a specific country comply with that country's national standards, that country experiences a positive impact on its export performance; (3) importing countries that adopt international standards experience an increase in imports; and (4) countries where importers adopt voluntary national standards may experience either positive or negative effects on imports, while countries where importers adopt mandatory national standards mostly experience a negative effect on imports (Swann, 2010).

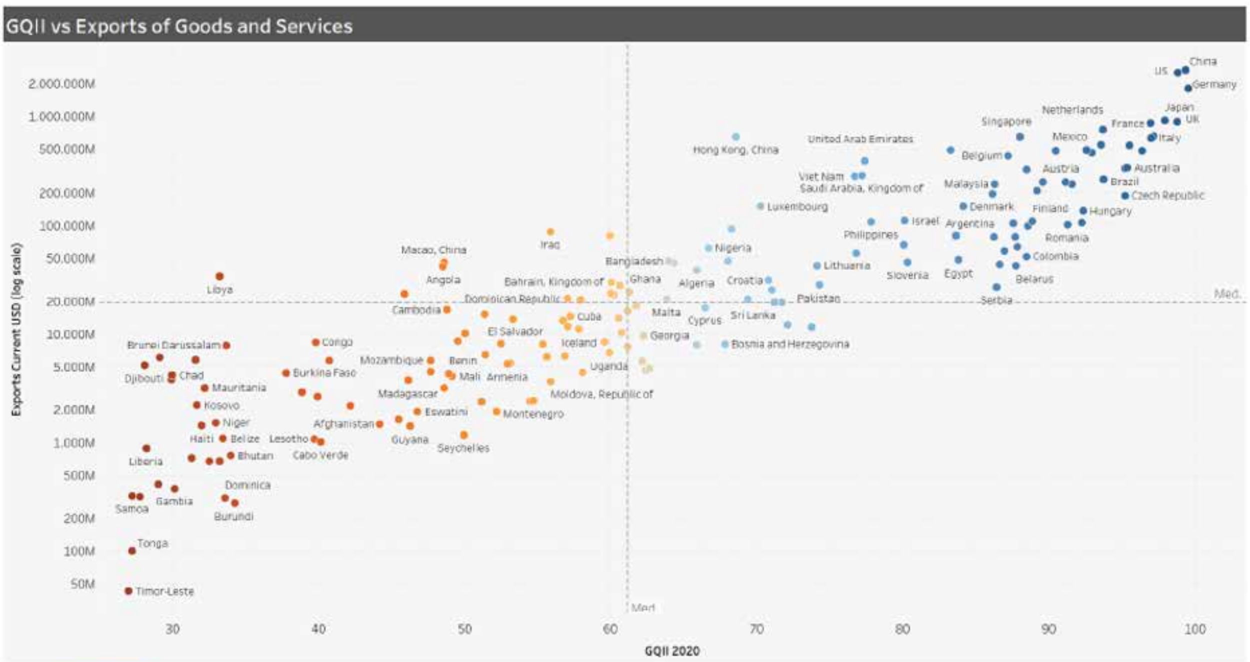
Beghin et al. (2015) conducted a comprehensive literature review on the impact of public and private quality standards in food markets, international trade and global supply chains. They focused mainly on studies that used quantitative approaches and found that the results were mixed regarding standards as a catalyst for or an impediment to trade and development (Beghin et al., 2015). Nevertheless, some key points emerged. Firstly, despite the emergence of stricter standards, global agriculture trade has increased sharply over the past few decades, particularly in sub-sectors where standards are most important, which often tend to be higher-value products (Beghin et al., 2015). Secondly, the surge of standards in trade has coincided with an increase in (foreign) investment and the restructuring of VCs, with VCs becoming more concentrated and increasingly organized through vertical coordination (Beghin et al., 2015). Thirdly, standards reduce transaction costs along value chains because they reduce information asymmetries between buyers and suppliers with respect to quality, safety, and other product characteristics (Beghin et al., 2015).

Blind et al. (2018) investigated the effects of cooperation in accreditation on international trade by looking at ISO 9000 certifications and membership to the Mutual Recognition Arrangement of the International Accreditation Forum (IAF MLA). Enterprises adopt standards to signal their commitment to quality upgrading and performance. Blind et al. (2018) claim that the effectiveness of this signal depends on the trust in the accreditation system and the level of development of the country and its QIS. The authors used an extended gravity model, applying a country-pair fixed effects regression approach with Instrumental Variables (IVs) and multilateral resistance terms. Their panel data set covers the period 1999 to 2012 and was built using data from the United Nation Statistical Division's COMTRADE Database and the 2015 International Organization for Standardization (ISO) survey. Their analysis revealed that standards certification promotes trade and that IAF MLA signatories trade significantly more. This is particularly relevant to developing and less developed countries as ISO certifications have a positive and significant effect on trade. This effect was intensified when the country was a signatory of the IAF MLA. Their findings support the expectation that QI has a positive effect on GVC integration, particularly for African countries, given that Africa is the least-developed continent, with the exception of Antarctica (World Population Review, 2022).
Aswal (2020) examined India's national QI system and compared it to the QI system of the United States of America - one of the strongest QI systems in the world. He highlighted that while the three main pillars of QI – metrology, accreditation and standardization - are well placed in India, they should be strengthened to enhance the growth of India's economy. More specifically Aswal (2020) indicated that the calibration and measurement capabilities of India's National Metrology Institute should be expanded to include energy, environment monitoring, biomedical, quantum standards and Indian Standard Time. He added that while a significant proportion of laboratories in the country has been accredited by the country's National Accreditation Body, several thousand remain unaccredited. Additionally, he underscored the need for India's National Standards Body to develop new Indian Standards for Micro, Small and Medium Enterprises (MSMEs). Aswal (2020) emphasized the importance of QI for the development of MSMEs, which accounted for 40% of India's exports in 2013 (Aswal, 2020). He argued that robust, internationally harmonized conformity assessment services and technical regulations are essential for the facilitation of imports and exports, and that deficiencies in these areas could result in technical barriers to trade that hinder imports and exports. Indian exporters are asked for proof of multiple tests and certifications before their products are allowed to enter foreign countries. They are also asked to comply with multiple standards. On several occasions the products of Indian exporters have been rejected at the border of foreign countries due to poor compliance with standards and conformity assessment requirements, resulting in significant economic losses for India (Aswal, 2020).

Inui et al. (2021) investigated whether and how a country's centrality in the GVCs of a particular sector is dependent upon the extent to which its regulatory regime differs from the global norm. They proxy for GVC centrality by calculating the Bonacich–Katz eigenvector centrality metric using Inter-Country Input-Output tables from the Organisation for Economic Co-operation and Development (OECD) to observe the relative position of each country-sector pair within a global production network (Inui et al., 2021). Exporters must comply with various technical regulations and standards when serving foreign markets and each country has its own set of regulations. Cross-country differences in regulations result in high compliance costs and technical difficulties for exporting firms, which affects their integration in GVCs since they must comply with the regulatory requirements in each of the countries along the VC (Inui et al., 2021). The authors found that the more similar a country's regulatory regime is to the global norm, the more likely it is for that country to play a dominant role in GVCs. Based on their findings, Inui et al. (2021) purport that countries can enhance their centrality in GVCs by harmonising their technical regulations to global standards. This is in line with the work of Gereffi et al. (2011), which underlined how international standards minimised complexities of cross-border transactions along GVCs.

Schmidt and Steingress (2022) contribute to the QI literature by investigating the effects of harmonized, voluntary product standards on trade integration. To test their hypothesis, they constructed a novel database on bilateral product-level trade flows and standard releases for 20 countries for the period 1995-2014 using the Searle Center Database on Technology Standards, Industry Consortia and Innovation. The authors estimated their model using a Difference-in-Difference approach and addressed endogeneity and robustness concerns using IV estimation. Their findings reveal that, on average, the introduction of harmonized standards increases product-level trade flows by 0.59%. Given the fact that harmonized standards are released in over 40% of all bilateral product-level trade flow pairs annually, Schmidt and Steingress (2022) estimate the average annual contribution to international trade growth to be 0.30 percentage points or 13%.

Harmes-Liedtke & Oteiza (2021b) introduced the GQII and used it to look at the relationship between QI and various indicators of economic development in their seminal report. The GQII encompasses the three main components of QI – standardization, metrology and accreditation. They examined the correlation of the GQII with GDP per capita, exports of goods and services and the Economic Complexity Index. They found that there was a strong correlation (0.89) between the GQII and exports. This is illustrated in Figure 5. They supported their findings with the arguments that a functioning QI system is a requirement of the World Trade Organization (WTO); and that WTO, as well as bilateral and multilateral, trade agreements explicitly refer to the use of mutual recognition of accredited conformity assessment services (Harmes-Liedtke & Oteiza, 2021b). Given the important role played by exports in both GVC measurement and participation, it is plausible to assume a connection between QI, measured using the GQII, and GVC participation too. In fact, according to Taglioni & Winkler (2016), the first consideration when assessing a country's potential in GVCs is its imports and exports.




Source: https://gqii.org/. Creative Commons licence apply.
Notes: Exports of goods and services 2019 in current USD (World Bank). Own calculations for GQII 2020. Log scale for Export axis. Significant correlation of 0,89.

Figure 5: Correlation between GQII and Exports
Source: Harmes-Liedtke & Oteiza (2021b)

## 4.2. UNDERDEVELOPED QI AS A HINDRANCE TO INTERNATIONAL TRADE

Kareem and Martínez-Zarzoso (2020) investigate how European Union (EU) food standards for fish products affect African fish exports. The authors look at whether EU food standards are more restrictive than the corresponding scientifically referenced international benchmarks - Codex Alimentarious[2] Commission (hereafter Codex) standards. More specifically, they try to determine whether the increased regulatory margin between EU standards and international harmonised standards might be more trade-distorting. Kareem and Martínez-Zarzoso (2020) use trade data for 27 EU and 40 African countries for the period 2007 to 2012 and employ the gravity model with two estimation approaches to account for the high frequency of zeros in their data. Their first approach is based on log-linear models and makes use of four linear methods – truncated pooled Ordinary Least Squares, taking the logarithm of the dependent variable, using fixed and random effects, and the Feasible Generalized Least Squares panel estimator technique. Their second approach is based on non-linear methods and makes use of two techniques – the Poisson Pseudo Maximum Likelihood model and the Multinomial Pseudo Maximum Likelihood Poisson model.

Their results showed that EU fish standards were not trade-inhibiting relative to the ones imposed by Codex. Additionally, despite the EU consistently rejecting fish exports from Africa that are non-compliant with EU standards, EU regulations are aligned with those specified by Codex. The authors, therefore, concluded that the large quantities of Africa's fish exports being prevented from entering the EU were not the consequence of protectionist EU standards but rather an indication of Africa's underdeveloped QI. They purported that inadequate domestic standards, as well as a lack of the scientific and technological ability to ensure and prove compliance, were greater barriers to trade for African countries than stringent food safety standards.

Nguyen and Jolly (2020) investigated how compliance with VietGAP, which encompasses all other international standards, affects the pangasius value chain and the industry structure as a whole. Vietnam is a major producer and exporter of pangasius. Since the industry is buyer-driven, producers and exporters must meet the demands of international customers for international food safety, quality and sustainability standards if they want to remain competitive (Nguyen & Jolly, 2020). The authors based their study on interviews with 41 processing and exporting firms and 91 farmers. A significant finding was that as the demand for international food safety, quality and sustainability standards increased in markets in the United States (US) and the EU, pangasius exports to these markets decreased, and Vietnamese exporters sought other market alternatives with less stringent quality requirements (Nguyen & Jolly, 2020). Farmers had the impression that the costs of adopting VietGAP outweighed the benefits (Nguyen & Jolly, 2020). At a first glance, it can be argued that the imposition of these standards is trade inhibiting since it prevents exporters from entering US and EU markets. However upon closer analysis of the data, production and exports did not decrease with the imposition of standards, instead they increased over time (Nguyen & Jolly, 2020). Additionally, the complexity of the industry and the structure of the value chain changed. Processing enterprises began integrating more with producers and some adopted a backward integration strategy where they either established their own farms to supply inputs or developed direct partnerships with producers, thereby making the role of collectors redundant (Nguyen & Jolly, 2020). Furthermore, the farmers who did not adopt VietGAP cited a lack of infrastructure and high costs as their main constraints and the majority of them indicated their willingness to adopt standards if support is provided (Nguyen & Jolly, 2020).

Demissie et al. (2021) analysed the capacity of Ethiopia's NQI to meet the demand for QI services along the coffee value chain (CVC). They found that most of the QI-related issues were found in the production and primary processing links. Most QI-related issues were due to inadequate accreditation, metrology and conformity assessment services. They also found some shortcomings concerning standardization. In addition to the lack of QI services to meet the demand along the CVC, a lack of awareness about QI among stakeholders was another prominent issue. These QI-related problems have a major impact on Ethiopia's coffee quality, resulting in significant financial losses (Demissie et al., 2021).

*[2] Codex is a collection of internationally recognised standards, guidelines and codes of practice relating to food, food production, food labelling, and food safety. They are jointly formulated by the FAO and the WHO to promote safety, quality and fairness in the international food trade.*

Demissie et al. (2022) also evaluated QI-related issues along the wheat value chain (WVC) in Ethiopia and used the CALIDENA methodology to make recommendations to strengthen the country's QIS. CALIDENA is a participatory methodology that aims to stimulate quality in value chains and systematically and sustainably support the improvement of the NQI in developing and transformation countries (Harmes-Liedtke & Schiel, 2016). Demissie et al. (2022) found that Ethiopia's WVC was subject to insufficient QI services and a lack of quality awareness, which hindered the sector's competitiveness.

Assoua et al. (2022) investigated the impact of changes in sanitary and phytosanitary (SPS) measures on Cameroon's cocoa exports. SPS[3] measures include technical regulations, standards and conformity assessment procedures – all of which are key QI components. They used a mixed methodological approach, supplementing interviews with major stakeholders in the cocoa sub-sector with a panel data analysis applying the gravity model on Cameroon's cocoa trade with 10 major importing countries from 2001 to 2017. Their findings showed that Cameroon's cocoa export was not significantly affected by SPS measures, or changes to SPS regulations, in the major importing countries. Assoua et al. (2022) purport that the non-compliance by cocoa exporters with the SPS measures in importing countries, and the subsequent rejection of their exports, indicate poor domestic standards and inadequate scientific and technical expertise. In other words, deficiencies in Cameroon's QIS was a hindrance to its international cocoa trade, not the implementation of SPS measures by importing countries.

[3] *The Uruguay Round Agreement on Agriculture defines SPS measures as measures taken to protect human, animal, and plant life from foodborne hazards related to contaminants, additives, chemicals, toxins, diseases carried by plants or animals; and to protect animals and plants from pests and diseases, prevent entry and contain the spread of pests and diseases in a territory or foreign territory (found in Assoua et al. (2022)).*

# 5 THE IMPACT OF QI ON GVC PARTICIPATION

We use country-level data to determine if QI has any impact on GVC participation. Firstly, we investigate whether QI affects GVC involvement on a global scale, and then we narrow the focus to understand its effects on African countries. The hypothesis is that QI has a positive effect on GVC participation and that a strong NQI is a key factor in GVC engagement. This is based on the strong positive relationship between the measure for level of QI development (Overall GQII Score) and the measures for backward and forward GVC participation, which is illustrated in Figure 6 and Figure 7.

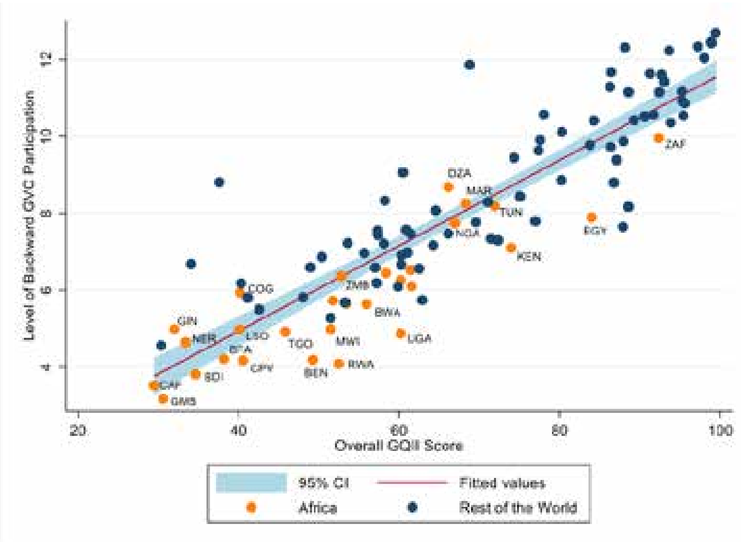



Figure 6: Relationship between QI and backward GVC participation


Figure 6: Relationship between QI and backward GVC participation

## 5.1. EMPIRICAL STRATEGY

We investigate the effect of QI on GVC participation by exploiting variation across countries and over time with respect to GVC participation and level of QI development. We estimate the impact of country decadal averages of QI development indicators on country decadal averages of GVC participation indicators using least squares between effects (LS-BE). This approach follows Fernandes et al. (2020) in their investigation of the factors that influence GVC participation. The main specification is presented in Equation (1):

$$Y_c = \beta_0 + \beta_1 * QI_c + \beta_2 * X_c + \varepsilon_c \qquad (1)$$

where c is country, Y is a measure of GVC participation, QI is a measure of QI development, X is a vector including previously studied determinants of GVC participation as controls, and ε is an independent and identically distributed error term. We use LS-BE estimation for the cross-country panel regression specified in Equation (1). The panel includes one observation per country, covering a decadal average from 2010 to 2020. The coefficients are identified through cross-country variations in GVC engagement and the variables of interest – the QI development indicators – as well as the control variables within the decade.

Three justifications underly the decision to use LS-BE estimation in this section. Firstly, GVC participation, the state of a country's NQI, as well as some of the determinants included as controls, change very slowly within countries from one year to another. Therefore it is likely that estimating Equation (1) using a within effects cross-country panel regression would produce less precise coefficients (Fernandes et al., 2020). In this case, using decadal averages presents more meaningful variation than year to year observations (Fernandes et al., 2020). Furthermore, decadal averages may address some of the measurement issues in level of QI development in the GQII, as well as in GVC engagement caused by errors in input-output tables. Additionally, using decadal averages enables the maximization of country coverage since countries remain in the estimating sample even if data is only available for some years during the decade (Fernandes et al., 2020). Secondly, LS-BE estimation takes advantage of the large cross-country variability in the data to identify the effects of QI on GVC integration with more precision.

Thirdly, until 2020 when the GQII was introduced, there were no comprehensive measures of overall QI development across countries. In other words, before 2020, there was no standardized cross-country data available to measure or compare the level of development of a country's overall QIS. Due to this, we take the 2020 GQII data as the decade average. Since the changes to a country's QIS that could significantly affect its GQII score takes place slowly, over several years, it is unlikely for their GQII ranks to change drastically from year to year (Tippmann, 2013). Therefore, it is plausible to use GQII data for 2020 as the decade average.

Four dependent variables are considered in Equation (1): (i) the share of backward GVC participation in gross exports, (ii) the level of backward GVC participation (logs), (iii) the share of forward GVC participation in gross exports, and (iv) the level of forward GVC participation (logs). The main independent variable of interest is the Overall GQII Score, which is used as a measure for the level of QI development. We also use individual measures for the three components of QI (standardization, metrology and accreditation) which together form the Overall GQII Score to understand if a specific QI element had a greater impact on GVC participation than the others.

## 5.2. DEFINITION AND MEASURES OF GVC PARTICIPATION

This working paper considers both backward and forward GVC participation as we expect QI to play a crucial role from the start to the end of GVCs. The analysis relies on the work of Fernandes et al. (2020) who built the dataset we adapted for the working paper. They construct the measures of backward and forward GVC participation so that trade flows cross the borders of at least two countries, which is a significant feature of GVC trade (Borin & Mancini, 2019; Fernandes et al., 2020).

For backward GVC participation Fernandes et al. (2020) rely on the work of Hummels et al. (2001), Borin and Mancini (2019) and Wang et al. (2013, 2017) who take into account the Leontief inverse matrix or the indirect effects where imported inputs are considered in domestic output, sometimes in several links along the value chain, before being used as inputs for exports. In their work, backward GVC participation measures the import content of a country's exports relative to its total gross exports (Fernandes et al., 2020). While the import content mostly comprises of foreign value-added, it can also include domestic value added which was previously exported (Fernandes et al., 2020).
Also for forward GVC participation, Fernandes et al. (2020) rely on the work of Borin and Mancini (2019). Forward GVC participation measures the domestic-value added in a country's exports that is used by its bilateral partner countries for export production as a percent of its total gross exports (Fernandes et al., 2020). It does not include the portion of domestic value added that is directly consumed by the bilateral partner in the final stage of the value chain (Fernandes et al., 2020).

A breakdown of how the GVC participation measures were constructed can be found in the Online Supplementary Appendix by Fernandes et al. (2021) for their paper "Determinants of Global Value Chain Participation: Cross-Country Evidence" and Borin and Mancini (2019)

Figure 8 presents the performance of African countries in GVCs, as well as reference lines highlighting the average share of backward and forward GVC participation for the entire sample. As can be seen, most African countries perform above the global average in upstream GVC activities, while only 28% perform above the global average in downstream activities. This could be because most African countries focus on extracting natural resources and agriculture, which generate inputs that are used in the manufacturing processes of their trading partners' exports.

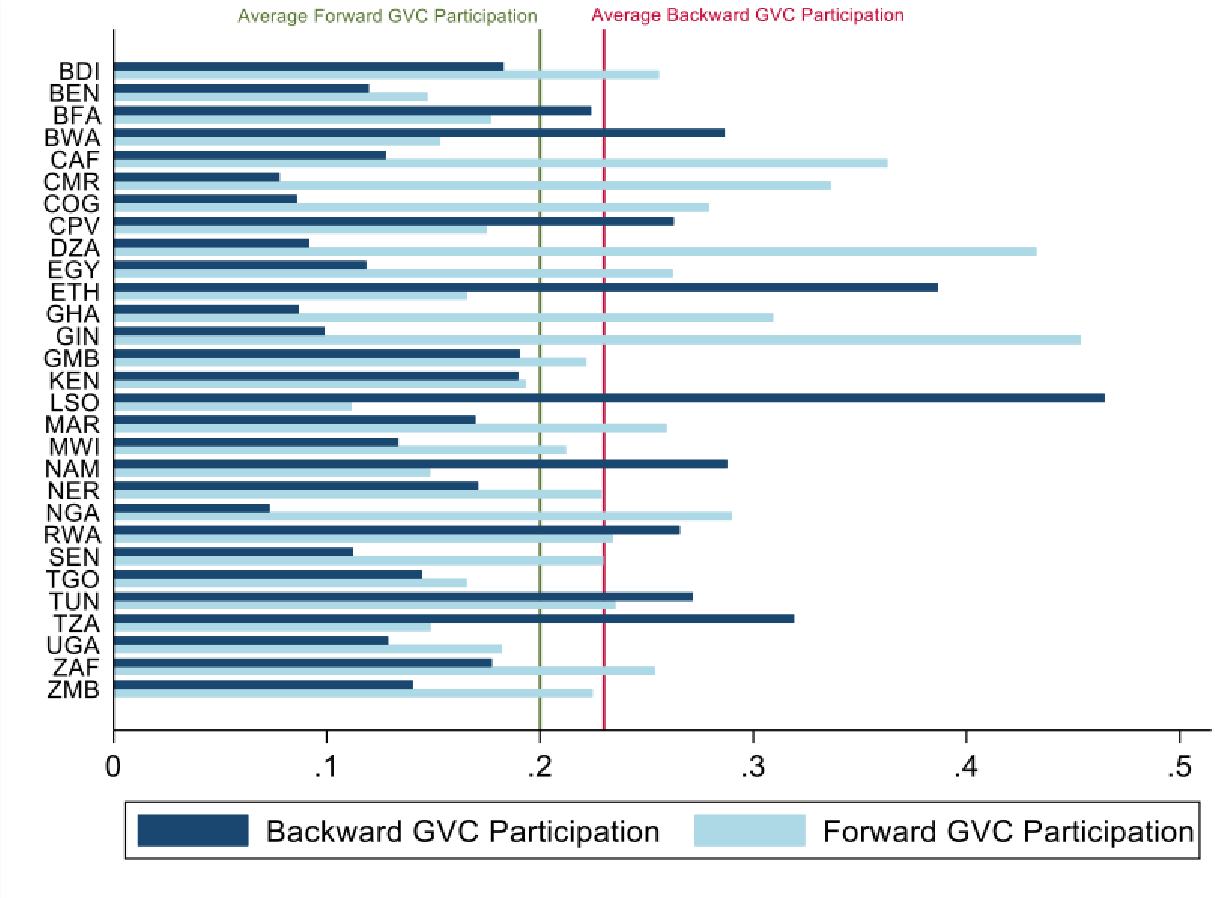



Figure 8: The GVC participation of African countries compared to global averages

## 5.3. MEASURES OF QI

We use the GQII as a measure for level of QI development. The GQII is a composite indicator that measures the level of QI development in countries (Harmes-Liedtke & Oteiza, 2021b). The indicator is constructed using published data on metrology, standardization, accreditation and conformity assessment from national and international QI organisations (Harmes-Liedtke & Oteiza, 2021b). The formula used to construct the GQII assumes that the three main components of QI – standardization, accreditation and metrology – contribute equally to a country's QIS (Harmes-Liedtke & Oteiza, 2021b). Each of these components themselves consist of several sub-indicators.

A more detailed breakdown of the formula and sub-indicators can be found in the Global Quality Infrastructure Index Report 2020 by Harmes-Liedtke & Oteiza (2021b). Countries are given a score depending on their level of development in each component. Then the formula is applied to these scores to calculate an overall GQII score out of 100. This overall score is then used to rank countries from first to last out of 184 countries. Countries with high overall scores will be top ranked with respect to the GQII and countries with low overall scores will be low ranked.

For this analysis we do not consider the rank itself but the overall score and the scores in the different components that comprise the overall score because the objective is not to compare countries to one another, but to examine whether their level of QI development affects their participation in GVCs. Additionally, although GQII data is available for 184 countries, this analysis only considers 103 countries due to the availability of data on GVC participation and the control variables.

The top five and bottom five countries in the sample according to the GQII ranking for 2020 are presented in Table 1. It is interesting to note that in the sample four out of the five lowest ranked countries according to the GQII in 2020 are in Africa.

Table 1: Top five and bottom five countries in the sample according to the GQII Ranking for 2020

| Country | GQII Accreditation Score | GQII Metrology Score | GQII Standardization Score | Overall GQII Score | GQII Rank 2020 |
|---|---|---|---|---|---|
| China | 0.995 | 0.991 | 0.996 | 99.408 | 2 |
| USA | 0.997 | 0.998 | 0.971 | 98.861 | 3 |
| UK | 0.987 | 0.989 | 0.989 | 98.833 | 4 |
| Japan | 0.962 | 0.990 | 0.987 | 97.983 | 5 |
| South Korea | 0.958 | 0.985 | 0.973 | 97.198 | 6 |
| | | | | | |
| Niger | 0.245 | 0.502 | 0.254 | 33.366 | 158 |
| Guinea | 0.311 | 0.460 | 0.188 | 31.973 | 166 |
| Gambia | 0.232 | 0.460 | 0.225 | 30.564 | 171 |
| Maldives | 0.232 | 0.460 | 0.217 | 30.322 | 173 |
| Central African Republic | 0.232 | 0.502 | 0.149 | 29.440 | 175 |

Source: Harmes-Liedtke and Oteiza (2021a)

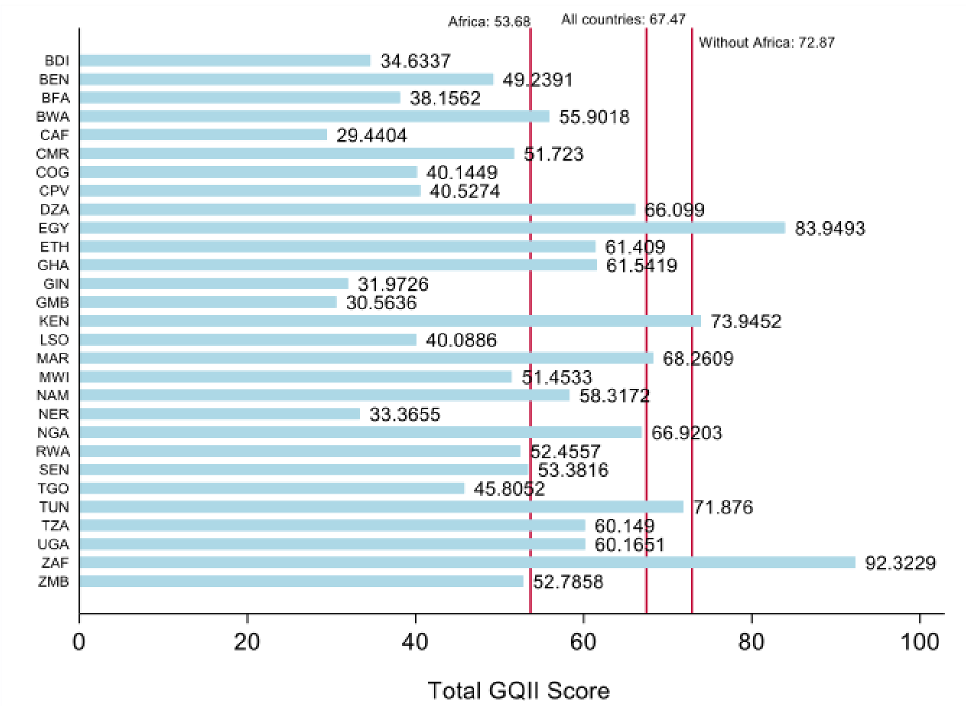



Figure 9: Overall GQII scores for African countries compared to the continental average, the global average, and the global average excluding African countries

Figure 9 presents the overall GQII scores for all African countries in the sample. We also include reference lines showing the mean overall GQII score for just Africa, for all countries, and for all countries excluding Africa. As can be seen, QI is very underdeveloped in Africa compared to the rest of countries in the sample. The mean overall GQII score in African countries (53.68) is much lower than the average overall GQII score for all countries (67.47) in the sample. Moreover, African countries bring down the global average as it is much higher when they are excluded from the analysis (72.87). Also noteworthy is that only five African countries (Egypt, Kenya, Morocco, Tunisia and South Africa) scored above the overall average, and three (Egypt, Kenya, South Africa) scored above the overall average which excluded African countries.

## 5.4. CONTROL VARIABLES

The control variables were selected based on the results of several studies conducted over two decades, which underscored these factors as significant contributors to GVC involvement.

Factor endowments, according to several classical models of trade, like the Heckscher-Ohlin model, play a significant role in determining which products countries choose to specialize in and by extension their positions in GVCs (Romalis, 2004). The analysis considers natural resources (rents from natural resource), high/medium and low skilled labour, and capital, all measured as a ratio to real GDP. An abundance of natural resources, capital and high/medium skilled labour have been found to enhance forward GVC participation, while low skilled labour is positively associated with backward GVC participation in the early stages (World Bank, 2019).

Geography is measured by geographical distance to GVC hubs (China, Germany, USA) (Li et al., 2019). Geography and distance play major roles in determining which countries to import from, which in turn affects a country's position along GVCs (Antràs & de Gortari, 2017; Eaton & Kortum, 2002; Farole, 2016; Raei et al., 2019). Trade costs compound along sequential GVCs, particularly in the downstream stages. These costs are amplified by inefficient transportation and logistics services especially when multiple border crossings are required. Therefore, remote countries may prefer to focus on upstream activities along GVCs rather than downstream activities (Fernandes et al., 2020). Further to this, geographic proximity has been found to be positively correlated with bilateral GVC links, while proximity to manufacturing hubs appears to be positively associated with backward GVC participation (Buelens & Tirpák, 2017; Kowalski et al., 2015).

Domestic industrial capacity is a major contributor to international trade according to the gravity model (Arkolakis et al., 2012); however its impact on GVCs is ambiguous. One the one hand it could lead to lower levels of backward GVC participation as countries with large domestic industrial capacities may choose to specialize in connecting stages of production along GVCs thereby minimizing imported inputs relative to domestic inputs (Fernandes et al., 2020). On the other hand countries with large domestic industrial capacities may have a higher demand for final goods for domestic consumption which could stimulate specialization in downstream GVC activities and in turn increase backward GVC engagement (Fernandes et al., 2020). In this analysis we measure domestic industrial capacities using domestic manufacturing value added, as done by Fernandes et al (2020).

Trade policy and FDI play crucial roles in GVC trade as intermediates and semi-finished products often cross international borders several times before reaching the final stage of the GVC. Regulatory trade barriers, such as tariffs and quotas, increase trade costs, which in turn affects the integration and positioning of countries in GVCs (Antràs & de Gortari, 2017). This is consistent with the results of Kowalski et al. (2015) who found that tariffs on imports and exports were negatively associated with GVC integration. Furthermore, Antràs and de Gortari (2017) find that trade barriers appear to have a greater impact on downstream stages in GVCs than on upstream stages. Additionally, Hummels et al. (1998) found that reducing trade barriers increases vertical specialization, which has implications on GVC engagement. Preferential Trade Arrangements (PTAs) are often used by countries to facilitate trade with their trading partners. For instance, a country can use a PTA to offer lower or zero tariffs to a trading partner. Orefice and Rocha (2014) find that deep PTAs stimulate both the creation of and the level of trade in production networks among member countries. We measure trade policy using the average manufacturing tariff rate, the number of trade agreement partners a country has and the average depth of trade agreements, as done by Fernandes et al. (2020).

With respect to FDI, Kowalski et al. (2015) found that openness to FDI had a positive relationship with backward GVC participation. This is consistent with the findings of the OECD (2015). More specifically both Kowalski et al. (2015) and the OECD (2015) note that inward FDI openness encourages both backward and forward GVC engagement. In this analysis, we use FDI inflows to measure FDI openness (Fernandes et al., 2020).

Institutional quality is measured using the Political Stability Index, where scores range from -2.5 (weak) to 2.5 (strong) (Fernandes et al., 2020). Institutional quality contributes significantly to deepening GVC participation, particularly in sectors that produce complex and specialized products (Dollar & Kidder, 2017). Contract enforcement and contract completeness play important roles in GVC engagement, and inefficiencies in these areas could be a hindrance to GVC involvement (Dollar & Kidder, 2017). Further to this, countries with good institutions have been found to have higher participation in complex GVCs than their counterparts with weak institutions, particularly for sectors that are sensitive to institutions (Dollar & Kidder, 2017). Additionally, Kowalski et al. (2015), Farole (2016) and Ge et al. (2020) found a significant positive relationship between institutional quality and GVC participation.

Connectivity plays a crucial role in GVC trade as unreliable and delayed deliveries of inputs and intermediates along VCs may disrupt production in GVCs and increase trade costs. Therefore, it is important for countries to have efficient and effective transportation, communications and logistics systems in place, especially if they are located in remote areas and are far away from GVC hubs (Farole, 2016; Kowalski et al., 2015). Djankov et al. (2006) find that trade decreases by 1% for each day a product shipment is delayed. Many developing country suppliers and lead firms list transport costs and capacity as one of their main obstacles to entering GVCs (OECD, 2013). Moreover, countries that have less efficient inland transportation networks may experience a decline in FDI investments if they lack natural resources and are mainly integrated into GVCs based on affordable labour (Memedovic et al., 2008). In this analysis, connectivity is measured by the number of days it takes to clear imports (Fernandes et al., 2020).

## 5.5. DATA

This analysis relies on two datasets. One was developed by Fernandes et al. (2020) for their paper, "Determinants of Global Value Chain Participation: Cross-Country Evidence." This dataset contains the dependent variables, as well as all the control variables included in the estimations. The next dataset was developed by Harmes-Liedtke and Oteiza (2021a) for the construction of the seminal GQII. This dataset contains the main dependent variables of interest – the measures for overall QI development, as well as the measures for the level of development with respect to individual components of QI – standardization, metrology and accreditation.

We merged these datasets together to create the dataset used in the analysis. Detailed definitions and data sources for the variables used in the analysis from both datasets can be found in Table 6. Table 7 presents the summary statistics for the variables used in this section, and their correlations are presented in Table 8 and Table 9.

## 5.6. RESULTS

### 5.6.1. THE IMPACT OF QI ON BACKWARD GVC PARTICIPATION

Starting with the impact of QI on backward GVC participation shares, Column (1) of Table 2 shows the estimation of Equation (1) with just the QI variable – Overall GQII Score – for the entire sample. The coefficient for Overall GQII Score is positive and significant at the 5% level suggesting that QI has a positive impact on backward GVC participation shares. To test that this effect is not spurious, we include the control variables in Column (2). The coefficient for Overall GQII Score increases in both significance and magnitude when the controls are included indicating that the effect is not driven by other factors.

With respect to the control variables, only five were significant at conventional levels. The coefficient for distance to GVC hubs was negative and significant, indicating that geography could be a major deterrent to backward GVC participation, which is in line with expectations based on the findings of previous studies. Domestic industrial capacity was negative and significant, indicating that countries with large domestic industrial capacities perhaps source their inputs from domestic suppliers instead of importing them, thereby reducing their shares of backward GVC participation. With respect to factor endowments, having larger land and/or natural resources endowments decreases backward GVC participation shares, which is in line with expectations since these countries may tend to focus on more upstream, rather than downstream activities. Trade policy is also an important determinant of backward GVC participation as higher average manufacturing tariff rates are linked to lower shares of backward GVC participation. The rest of the control variables, even though the effects of most of them went in the expected direction, were insignificant at conventional standards.

In Columns (3) and (4), we estimate Equation (1) with only the variable of interest and then with controls, respectively, on just the African countries in the estimating sample to determine if the patterns that emerged in the previous estimations are the same for Africa. In the estimating sample, only 29 out the 103 countries are in Africa. The QI variable is insignificant in both estimations, as are most of the control variables. Only medium/high skilled labour was statistically significant and exhibited a negative impact on the share of backward GVC participation of African countries. This could be because medium/high skilled labour is positively linked to forward GVC participation. A possible reason for the mostly insignificant results could be because there are too few observations to obtain significant or stable results. This is further compounded by the low levels of QI development and shares of backward GVC involvement of most African countries, as illustrated in Figure 2, Figure 8 and Figure 9.

In Columns (5) and (6) we repeat the process, this time excluding African countries from the estimating sample. In both estimations the coefficients for the QI variable were positive and significant. The coefficients for distance to GVC hubs, domestic industrial capacity, and land and natural resources endowments were similar to Column (2) – negative and statistically significant. This provides some reassurance about the validity of the results. The coefficient for trade policy remains the same as in Column (2) in terms of sign and magnitude, however, it loses significance. The coefficient for capital endowments increases in magnitude and becomes significant at the 5% level suggesting that higher levels capital endowments have positive effect on backward GVC engagement. This is consistent with expectations since the production processes in backward GVC involvement require capital investments, therefore having large capital endowments can facilitate backward GVC participation.

A possible explanation for the increase in significance and magnitude of the coefficient for capital could be that many African countries have lower levels of capital endowments compared to other countries. The remaining variables' coefficients were not significantly different from zero. The results in Column (6) suggests that the patterns in Column (2) were predominantly driven by non-African countries. Furthermore, the impact of the factors on backward GVC participation may vary for African and non-African countries. However, it is difficult to confirm this since there are too few observations for African countries.

Table 2: Share of backward GVC participation

| | Share of Backward GVC Participation | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | Share of Backward GVC Participation | | | | | |
| | | | | | | |
| Overall GQII Score | 0.002** | 0.004*** | -0.000 | 0.001 | 0.002* | 0.004** |
| | (0.001) | (0.001) | (0.001) | (0.003) | (0.001) | (0.002) |
| Distance to GVC hubs (log) | | -0.093** | | 0.032 | | -0.107* |
| | | (0.045) | | (0.222) | | (0.056) |
| Time to import (log) | | 0.001 | | 0.001 | | 0.001 |
| | | (0.001) | | (0.003) | | (0.001) |
| Political stability index | | 0.022 | | -0.038 | | 0.023 |
| | | (0.020) | | (0.055) | | (0.025) |
| Domestic industrial capacity (log) | | -0.045*** | | -0.056 | | -0.046*** |
| | | (0.012) | | (0.038) | | (0.013) |
| Rents from resources / GDP (%) | | -0.003** | | -0.003 | | -0.004* |
| | | (0.001) | | (0.003) | | (0.002) |
| Land / GDP (log) | | -0.019** | | -0.004 | | -0.021** |
| | | (0.007) | | (0.021) | | (0.010) |
| Capital / GDP (log) | | 0.042 | | -0.023 | | 0.084** |
| | | (0.032) | | (0.082) | | (0.040) |
| Medium/High-skilled labour / GDP (log) | | -0.004 | | -0.069** | | 0.008 |
| | | (0.018) | | (0.030) | | (0.043) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Low-skilled labour / GDP (log) | | 0.008 | | 0.058 | | -0.004 |
| | | (0.017) | | (0.033) | | (0.029) |
| FDI inflows (log) | | 0.012 | | 0.020 | | 0.019 |
| | | (0.011) | | (0.023) | | (0.014) |
| Avg. tariff rate (%) | | -0.004* | | -0.001 | | -0.004 |
| | | (0.003) | | (0.008) | | (0.003) |
| No. of trade agreement partners (log) | | -0.008 | | -0.050 | | -0.040 |
| | | (0.036) | | (0.103) | | (0.050) |
| Avg. depth of trade agreements (log) | | 0.013 | | 0.044 | | 0.033 |
| | | (0.024) | | (0.059) | | (0.035) |
| | | | | | | |
| Observations | 103 | 101 | 29 | 29 | 74 | 72 |
| R-squared | 0.062 | 0.498 | 0.001 | 0.622 | 0.050 | 0.553 |
| Number of ISO2 | 103 | 101 | 29 | 29 | 74 | 72 |
| Standard errors in parentheses | | | | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | | | | |

Table 3 shows the impact of QI (Overall GQII Score) on the level of backward GVC participation. We repeat the estimations from Table 2, this time using level of backward GVC participation (log) as the dependent variable. In Columns (1) and (2) (estimations with full sample) the coefficient for QI is positive and significant, even when we include the control variables, indicating that QI plays an important role in the level of backward GVC participation. In Column (2) the coefficient for geography is negative and significant highlighting the importance of being close to GVC hubs for backward GVC participation. The coefficients for land endowments and medium/high skilled labour were both negative and significant suggesting that higher levels of these factor endowments were associated with lower levels of backward GVC participation. The effect of domestic industrial capacity changed direction and now exhibited a positive effect on the level of backward GVC participation. This could be because countries with large domestic industrial capacities might demand more final goods for domestic consumption, thereby encouraging specialization in downstream GVC activities and in turn spurring backward GVC engagement (Fernandes et al., 2020). Also positive and significant is the coefficient for FDI inflows, which is consistent with expectations. The remaining control variables were not significantly different from zero.

In Columns (3) and (4) we narrow the focus to just the African countries in the sample. The QI variable was positive and significant at the 1% level in Column (3) but loses significance completely in Column (4) when we include control variables. The only significant results are the coefficients for endowments from natural resources which exhibited a positive effect on the level of backward GVC participation for African countries, and medium/high skilled labour which has a negative effect. Again, the mostly insignificant results could be due to the low number of African countries in the estimation sample.

In Columns (5) and (6) we exclude African countries from the estimations. The coefficient for the QI variable regains its significance and is positive in both estimations. Also positive and significant in Column (6) are the coefficients for political stability, domestic industrial capacity, capital endowment and FDI inflows indicating that these factors are associated with higher levels of backward GVC participate in non-African countries. The coefficient for land endowments is negative and significant and the coefficient for medium/high skilled labour loses significance completely. Again, the results in Columns (4) and (6) indicate that the different determinants have different impacts and intensities in Africa compared to the RoW.

Table 3: Level of backward GVC participation

| | Share of Backward GVC Participation (log) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | Level of Backward GVC Participation (log) | | | | | |
| | | | | | | |
| Overall GQII Score | 0.111*** | 0.026*** | 0.093*** | 0.034 | 0.102*** | 0.021* |
| | (0.006) | (0.010) | (0.010) | (0.022) | (0.007) | (0.012) |
| Distance to GVC hubs (log) | | -0.608* | | 0.758 | | -0.503 |
| | | (0.334) | | (1.507) | | (0.410) |
| Time to import (log) | | 0.009 | | -0.006 | | 0.008 |
| | | (0.007) | | (0.018) | | (0.010) |
| Political stability index | | 0.187 | | -0.420 | | 0.345* |
| | | (0.147) | | (0.372) | | (0.183) |
| Domestic industrial capacity (log) | | 0.516*** | | 0.296 | | 0.506*** |
| | | (0.088) | | (0.257) | | (0.098) |
| Rents from resources / GDP (%) | | -0.003 | | 0.043** | | -0.013 |
| | | (0.010) | | (0.020) | | (0.013) |
| Land / GDP (log) | | -0.142*** | | 0.095 | | -0.139* |
| | | (0.053) | | (0.141) | | (0.071) |
| Capital / GDP (log) | | 0.355 | | 0.601 | | 0.568* |
| | | (0.239) | | (0.558) | | (0.295) |
| Medium/High-skilled labour / GDP (log) | | -0.293** | | -0.633*** | | -0.131 |
| | | (0.131) | | (0.206) | | (0.315) |
| Low-skilled labour / GDP (log) | | -0.000 | | -0.014 | | -0.045 |
| | | (0.128) | | (0.224) | | (0.213) |
| FDI inflows (log) | | 0.153* | | 0.020 | | 0.272*** |
| | | (0.079) | | (0.157) | | (0.101) |
| Avg. tariff rate (%) | | -0.032 | | 0.011 | | -0.033 |
| | | (0.020) | | (0.056) | | (0.023) |
| No. of trade agreement partners (log) | | 0.174 | | 0.110 | | 0.078 |
| | | (0.269) | | (0.699) | | (0.364) |
| Avg. depth of trade agreements (log) | | -0.142 | | 0.214 | | -0.030 |
| | | (0.179) | | (0.398) | | (0.259) |
| | | | | | | |
| Observations | 103 | 101 | 29 | 29 | 74 | 72 |
| R-squared | 0.792 | 0.926 | 0.770 | 0.943 | 0.743 | 0.910 |
| Number of ISO2 | 103 | 101 | 29 | 29 | 74 | 72 |
| Standard errors in parentheses | | | | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | | | | |

We repeat the estimations from Table 2 and Table 3 for individual components of the Overall GQII Score to determine the effects of specific QI elements on the share and level of backward GVC participation. The results for standardization and metrology are presented in Table 10 and Table 11 respectively. As can be seen in Table 10 the coefficient on the QI measure for standardization is positive and significant in the baseline estimations for both the share and level of backward GVC participation, which is in line with expectations. However, once again the results were inconclusive when we limited the estimation sample to only African countries due to the small sample size.

According to the results in Table 11, metrology plays a crucial role in backward GVC participation. The coefficient for metrology was positive and significant for most of the estimations for both the share and level of backward GVC involvement.

With respect to the impact of accreditation on both the share and level of backward GVC participation, the coefficient was only significant in the estimations without control variables. Due to the mostly insignificant findings, the results of these estimations are not included in the Appendix.

### 5.6.2. THE IMPACT OF QI ON FORWARD GVC PARTICIPATION

Next, we focus on the impact of QI on the share of forward GVC participation. We repeat the estimations from Table 2, but now with the share of forward GVC participation as dependent variable. The results are presented in Table 4. The QI variable is insignificant at conventional levels in most of the estimations. In Column (2), which presents the results of estimating the baseline equation with controls on the full sample, only some of the measures of factor endowments and trade policy were significant. The coefficients for resource and land endowments were both positive and significant suggesting that countries with higher levels of these factor endowments are more likely to be involved in forward GVC participation. The coefficient for low-skilled labour was negative and significant, suggesting that high levels of low-skilled labour is linked to low shares of forward GVC participation. This is in line with expectations since previous studies have found that low-skilled labour is positively associated with backward GVC participation. With respect to trade policy, the coefficient for number of trade partners was positive and significant, while the coefficient for depth of trade agreements was negative. While the findings for number of trade partners is expected, a negative sign on the coefficient for dept of agreements is surprising as Orefice and Rocha (2014) found that deeper trade agreements stimulated GVC trade among countries.

In Column (4), which shows the results of the estimation with control variables on only African countries, all the variables have insignificant coefficients, except for number of trade partners, which is positive and significant. This suggests that, for African countries, having a higher number of trade partners is associated with higher shares of forward GVC participation. However, the low number of observations for African countries make it difficult to draw conclusions from the results of the estimations in Columns (3) and (4).

Table 4: Share of Forward GVC participation

| | Share of Forward GVC Participation | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | Share of Forward GVC Participation | | | | | |
| | | | | | | |
| Overall GQII Score | 0.000 | -0.000 | -0.000 | -0.002 | 0.001** | 0.000 |
| | (0.000) | (0.001) | (0.001) | (0.003) | (0.000) | (0.001) |
| Distance to GVC hubs (log) | | -0.029 | | -0.082 | | -0.047 |
| | | (0.027) | | (0.180) | | (0.031) |
| Time to import (log) | | -0.000 | | -0.000 | | 0.000 |
| | | (0.001) | | (0.002) | | (0.001) |
| Political stability index | | -0.010 | | -0.023 | | 0.002 |
| | | (0.012) | | (0.045) | | (0.014) |
| Domestic industrial capacity (log) | | 0.011 | | 0.009 | | 0.007 |
| | | (0.007) | | (0.031) | | (0.007) |
| Rents from resources / GDP (%) | | 0.003*** | | 0.001 | | 0.003*** |
| | | (0.001) | | (0.002) | | (0.001) |
| Land / GDP (log) | | 0.010** | | 0.007 | | 0.008 |
| | | (0.004) | | (0.017) | | (0.005) |
| Capital / GDP (log) | | -0.022 | | -0.067 | | -0.007 |
| | | (0.019) | | (0.067) | | (0.022) |
| Medium/High-skilled labour / GDP (log) | | 0.017 | | 0.009 | | 0.000 |
| | | (0.011) | | (0.025) | | (0.024) |
| Low-skilled labour / GDP (log) | | -0.026** | | -0.017 | | -0.013 |
| | | (0.010) | | (0.027) | | (0.016) |
| FDI inflows (log) | | -0.005 | | 0.004 | | -0.004 |
| | | (0.006) | | (0.019) | | (0.008) |
| Avg. tariff rate (%) | | 0.001 | | -0.002 | | -0.000 |
| | | (0.002) | | (0.007) | | (0.002) |
| No. of trade agreement partners (log) | | 0.052** | | 0.151* | | 0.032 |
| | | (0.022) | | (0.084) | | (0.028) |
| Avg. depth of trade agreements (log) | | -0.030** | | -0.072 | | -0.024 |
| | | (0.014) | | (0.048) | | (0.020) |
| | | | | | | |
| Observations | 103 | 101 | 29 | 29 | 74 | 72 |
| R-squared | 0.000 | 0.461 | 0.001 | 0.656 | 0.056 | 0.400 |
| Number of ISO2 | 103 | 101 | 29 | 29 | 74 | 72 |
| Standard errors in parentheses | | | | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | | | | |

To find out if QI has any impact on the level of forward GVC participation, we repeat the estimations in Table 4, but with level of forward GVC participation (log) as the dependent variable. The results are presented in Table 5. The measure for QI – the overall GQII score – has a positive coefficient for all the estimations but is only significant in the estimations that exclude control variables, suggesting that the results might be spurious. With respect to the control variables, the majority have insignificant coefficients. In Column (2), which shows the results of estimating the baseline model with controls on the full sample, as expected, the coefficient for domestic industrial capacity is positive and significant. When the estimation was repeated with just African countries, seen in Column (4), domestic industrial capacity completely loses significance. However, it regains its significance when the estimation excludes African countries from the sample, seen in Column (6). This could be because most African countries have smaller domestic industrial capacities compared to other countries. It could also be attributed to the small number of African countries in the sample. In addition, the estimation in Column (2) shows that the coefficient for natural resource endowment is positive and significant. The results remain consistent in Column (4), suggesting that African countries with large resource endowments have a higher level of forward GVC participation, which is in line with expectations.

Table 4: Share of Forward GVC participation

| | Level of Forward GVC Participation (log) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | Level of Forward GVC Participation (log) | | | | | |
| | | | | | | |
| Overall GQII Score | 0.105*** | 0.011 | 0.094*** | 0.013 | 0.101*** | 0.009 |
| | (0.006) | (0.010) | (0.016) | (0.033) | (0.008) | (0.012) |
| Distance to GVC hubs (log) | | -0.400 | | 0.352 | | -0.353 |
| | | (0.330) | | (2.251) | | (0.390) |
| Time to import (log) | | 0.007 | | -0.007 | | 0.009 |
| | | (0.007) | | (0.026) | | (0.009) |
| Political stability index | | 0.061 | | -0.316 | | 0.263 |
| | | (0.145) | | (0.555) | | (0.175) |
| Domestic industrial capacity (log) | | 0.775*** | | 0.671 | | 0.745*** |
| | | (0.087) | | (0.384) | | (0.094) |
| Rents from resources / GDP (%) | | 0.028*** | | 0.061* | | 0.019 |
| | | (0.010) | | (0.030) | | (0.013) |
| Land / GDP (log) | | -0.041 | | 0.089 | | -0.044 |
| | | (0.053) | | (0.211) | | (0.067) |
| Capital / GDP (log) | | 0.133 | | 0.380 | | 0.289 |
| | | (0.237) | | (0.834) | | (0.281) |
| Medium/High-skilled labour / GDP (log) | | -0.185 | | -0.296 | | -0.192 |
| | | (0.130) | | (0.307) | | (0.300) |
| Low-skilled labour / GDP (log) | | -0.176 | | -0.294 | | -0.098 |
| | | (0.127) | | (0.335) | | (0.203) |
| FDI inflows (log) | | 0.070 | | -0.033 | | 0.143 |
| | | (0.078) | | (0.234) | | (0.097) |
| Avg. tariff rate (%) | | -0.007 | | 0.019 | | -0.019 |
| | | (0.019) | | (0.083) | | (0.022) |
| No. of trade agreement partners (log) | | 0.374 | | 0.991 | | 0.266 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | (0.266) | | (1.044) | | (0.347) |
| Avg. depth of trade agreements (log) | | -0.303* | | -0.340 | | -0.235 |
| | | (0.177) | | (0.594) | | (0.247) |
| | | | | | | |
| Observations | 103 | 101 | 29 | 29 | 74 | 72 |
| R-squared | 0.735 | 0.925 | 0.577 | 0.906 | 0.704 | 0.920 |
| Number of ISO2 | 103 | 101 | 29 | 29 | 74 | 72 |
| Standard errors in parentheses | | | | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | | | | |

In order to find out if the results for the QI variable in Table 4 and Table 5 are driven by specific QI components, we repeat the estimations, replacing Overall GQII Score with individual measures for standardization, metrology and accreditation. With respect to the impact of standardization on the share of forward GVC participation, the coefficient is only significant in the estimation with controls that excluded African countries; and as expected the sign is positive. When we replace share of forward GVC participation with level of forward GVC participation as the dependent variable, the coefficient on the measure for standardization is positive, but only significant in the estimations without control variables, suggesting a spurious effect.

With respect to the impact of metrology on forward GVC participation, the coefficient for GQII Metrology Score is insignificant in all the estimations with share of forward GVC participation as the dependent variable. When we repeat the estimations with level of forward GVC participation as dependent variable, the coefficient for the metrology measure is positive and significant only in the two baseline estimations on the entire sample, and the estimation with all the controls that excludes Africa from the sample.

Regarding the effect of accreditation on forward GVC participation, the coefficient for the GQII Accreditation Score was insignificant for all the estimations with share of forward GVC participation as the dependent variable. When we used level of forward GVC participation as the dependent variable, only the estimations without control variables were significant, indicating that the relationship is not robust.

The estimations with the share and level of forward GVC participation, and individual measures for standardization, metrology and accreditation are not presented in the Appendix due to the mostly insignificant results.
One possible reason for these findings could be the low level of QI development in many of the countries that predominantly participate in upstream GVC activities. Many countries with high shares of forward GVC participation had low overall GQII scores.

## 5.7. LIMITATIONS

It is difficult to establish causality due to limitations of the data. Firstly, several limitations arise when relying on international input-output tables to measure GVC participation. In some cases, input-output tables have to be constructed or estimated in the absence of the "real" data. For instance, the Eora database, used for the analysis, uses interpolations and estimations for countries that do not produce national supply-use tables (Fernandes et al., 2020). This could result in measurement errors. These measurement errors may cause biased coefficients. It is difficult to address this issue because alternative sources of data to measure GVC participation do not cover as many countries, particularly African countries, as the Eora database and running the regressions with a limited sample could also lead to biased results. For instance, the 2021 version of the TiVA database includes data on 66 countries, however only three are African (Morocco, South Africa, Tunisia) (OECD, 2021). Moreover, the coverage of the World Input-Output Database is even more limited as the 2016 Release includes 43 countries, none of which are in Africa, and covers the period 2000 to 2014 (WIOD, 2016).

In addition, there is a number of limitations with respect to measuring the level of QI development. While the analysis covers the decade 2010 to 2020, data is only available for the year 2020 or later. Furthermore, at the time of writing and as already mentioned, there were only two publicly available cross-country measures for overall QI development. One is the GQII, which was used in the analysis. The other is the Quality Infrastructure for Sustainable Development (QI4SD) Index which was launched in June 2022 (UNIDO, 2022). However, the QI4SD Index was designed to measure the contribution of QI to the SDGs at the national level (UNIDO, 2022). Therefore scores that countries receive with respect to their level of QI development are based on, to some extent, their interactions with the SDGs (UNIDO, 2022). As such, it is difficult to consider the QI4SD Index strictly as a QI development indicator.

Another cross-country measure of overall QI development is the PAQI Index, which is available for 2014, 2017 and 2020. However, it only covers African countries and therefore cannot facilitate global comparisons. Furthermore, this data is not publicly available and all attempts to access it have been futile.

There are also some criticisms related to the GQII. One is that the indicators used to score countries on their level of development in the different QI components only provide a limited reflection of the country's performance in that particular QI component (Harmes-Liedtke & Oteiza, 2021b). Another criticism is that the GQII does not cover QI in its entirety as certain elements, such as technical regulations, quality promotion and legal metrology, do not receive adequate individual attention (UNIDO, 2022). Nevertheless, the GQII is the only available indicator that maps the overall development of a country's NQI.

6

# CONCLUSION

Until now, the essential role of QI in facilitating GVC participation has been underexplored in both QI and GVC literature. This working paper aims to draw attention to this gap and contribute to the initial findings and discussions. It investigates the impact of QI on GVC participation, with a focus on African countries, using a country-level approach. It also tries to understand whether it is necessary for African countries to further develop their QI ecosystems to become more integrated in GVCs. This area of research is especially relevant to African countries because the majority of them remain largely underrepresented in GVC trade, which stymies their development as they miss the numerous opportunities and benefits associated with GVC trade.

The results reveal that overall QI development plays a significant role in both the share and intensity of backward GVC participation. With respect to the individual QI components, the results suggest that standardization and metrology are important facilitators of backward GVC engagement. These are all plausible findings because of the often more complex and technical nature of the activities involved in backward GVC engagement.

Additionally, the findings of the country-level analysis implies that QI does not play a significant role in forward GVC participation. However, in reality this is not the case as QI plays a role in each stage of the value chain (Wipplinger et al., 2006). Some activities associated with forward GVC participation, such as extracting oil and natural gas, make extensive use of QI services. It is likely that the insignificant results may be due to many countries moving up the value chain and reallocating their resources to increase their share of backward GVC participation at the expense of their upstream GVC activities. It is also likely that the countries that specialise in upstream GVC activities have poorly developed NQIs and instead use third-party QI service providers in neighbouring countries, which is not accounted for in the data. In addition, it could be that there is a higher level of informality in many of the countries that have large shares of forward GVC participation, resulting a weak quality culture in society and less attention being given to QI requirements. Additionally, countries with a high share of forward GVC participation perhaps engage in activities or choose trade partners with less stringent QI requirements.

It is difficult to make inferences from the results when focus is placed on African countries for a few reasons. Firstly, data is available on only about 53% of the continent; more observations are needed for stable results. Secondly, the majority of African countries have poorly developed QI ecosystems with almost half of the continent having little or no QI capabilities. In the estimation sample, only Egypt, Kenya, Morocco, Tunisia and South Africa were on par with the world average with respect to overall QI development. Thirdly, Africa's overall GVC participation is much lower than the RoW. This is even more pronounced in terms of the continent's share of backward GVC participation, as the majority of African countries engage in more upstream GVC activities. In the estimation sample, only eight African countries – Botswana, Cabo Verde, Ethiopia, Lesotho, Namibia, Rwanda, Tunisia and Tanzania - were on par with the global average with respect to share of backward GVC participation.

Based on these results, it is clear that QI plays an important role in GVC engagement and that all countries seeking to become embedded in GVCs should invest in the development of their QI ecosystems. If QI services are not locally available, firms may be forced to use QI services in third countries to prove that their products and processes comply with specific standards or technical regulations. This significantly increases the sunk costs of GVC trade and decreases their competitiveness (Guasch et al., 2007; Mikhnev, 2018; Wipplinger et al., 2006). This is also true for African countries. This has been confirmed in previous studies (Assoua et al., 2022; Demissie et al., 2021, 2022; Kareem & Martínez-Zarzoso, 2020) which found that Africa's exports are affected because of insufficient QI capabilities. Therefore, if Africa intends to capitalize on the opportunities at hand to become more engaged in GVCs it is crucial for the continent to develop its QI ecosystem.

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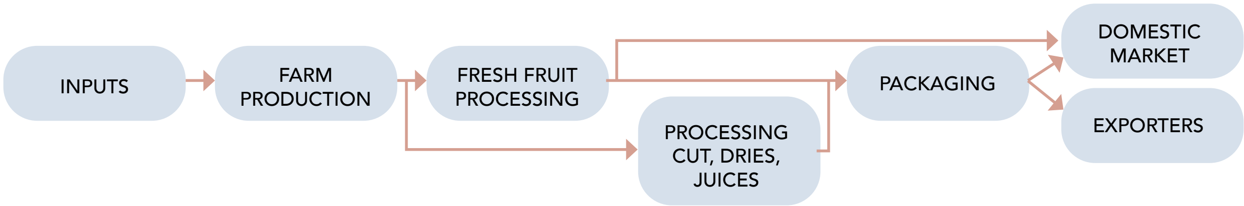
# APPENDIX A: QUALITY INFRASTRUCTURE




| STANDARDS | | | | |
|---|---|---|---|---|
| Code of practice planting materials | Good agricultural practices | Product quality standard | Fruit juice standard | Voluntary standards |
| Banned pesticides | Food safety / HACCP | Water treatment | Quality management systems ISO22000, ISO9001 | Country regulations |
| | Organic production | Organic standards | HACCP Organic | Food Safety Modernation Act (FDA) |
| | Global GAP / Fair Trade | Quality, food safety | | EU Regaulation |
| | Pesticide control | | | Pesticide residues |
| | Social standards | | | SPS, traceability |
| | | | | Labels |

| INSPECTION & CERTIFICATION | | | |
|---|---|---|---|
| | Inspectors SPS, GAP, GHP | | Quality |
| | Quality and PS auditors | Product certification | Inspectors |
| | | Quality management certification | |
| Private voluntary certification (Organic, Fairtrade, Global GAP) | | | |

| TESTING / LABORATORIES | | | |
|---|---|---|---|
| | Soil Testing | Pesticide residue testing | |
| | Pesticides | Microbiology testing | |

Figure 10: Mango value chain and related QI activities
Source: Kellermann and Keller (2015)

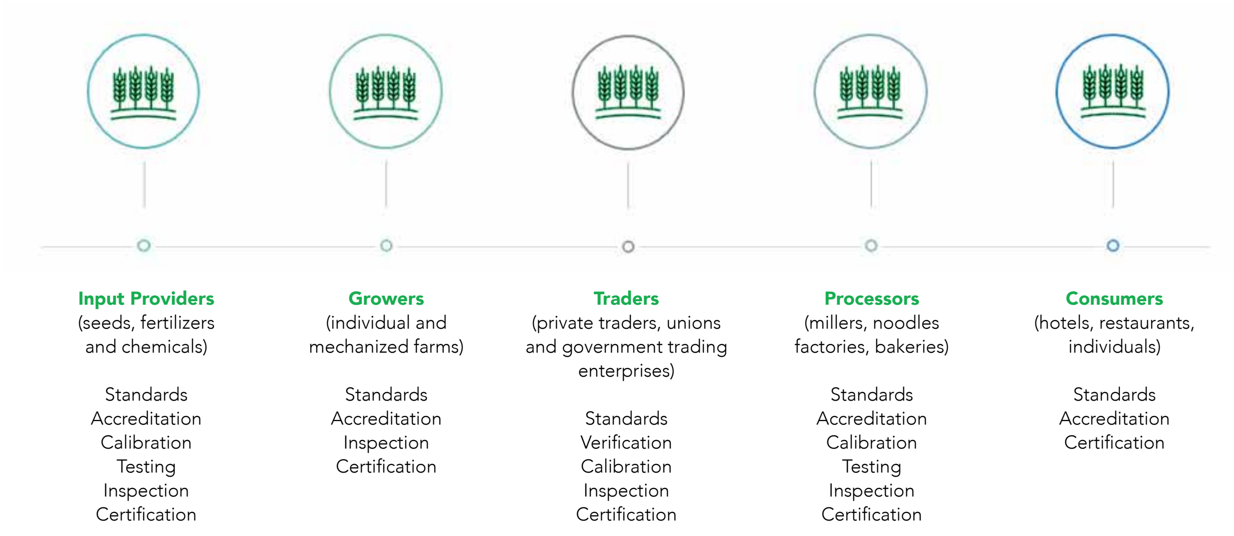



Figure 11: Wheat value chain and related QI requirements
Source: Adapted from Demissie et al. (2022)

# APPENDIX B: IMPACT OF QI ON GVC PARTICIPATION

| Variable Name | Definition | Source |
|---|---|---|
| Overall GQII score | An overall score out of 100 that measures the level of a country's QI development | GQII |
| GQII accreditation score | The accreditation component of the Overall GQII Score | GQII |
| GQII metrology score | The metrology component of the Overall GQII Score | GQII |
| GQII standardization score | The standardization component of the Overall GQII Score | GQII |
| Avg. tariff rate (%) | Applied tariff rate to manufactured products, weighted mean (in %) | WDI |
| FDI inflows (log) | Logarithm of net foreign direct investment inflows (in millions of USD) | UNCTAD |
| Distance to GVC hubs (log) | Logarithm of sum of distance to China, Germany and the US (capital city-to-capital city) | CEPII |
| Domestic industrial capacity (log) | Manufacturing value added (in current USD) obtained by multiplying nominal GDP with the share of manufacturing in value-added | WDI |
| Political stability index | Political stability and absence of violence/terrorism: Estimate | World Governance Indicators |
| Rents from resources / GDP (%) | Total natural resources as a percentage of GDP | WDI |
| Capital / GDP (log) | Logarithm of real capital stock (in constant 2011 national prices in mil. 2011 US$) divided by real GDP (in constant 2010 USD) | Penn World Tables 9.0, WDI |
| Land / GDP (log) | Logarithm of land area (sq. km) divided by real GDP (in constant 2010 USD) | WDI |
| Low skilled labour / GDP (log) | Logarithm of the share of employment of skill level 1 (low) according to the International Standard Classification of Occupations in total employment https://www.ilo.org/public/english/bureau/stat/isco/isco08/index.htm | ILO |
| Medium/High skilled labour / GDP (log) | Logarithm of the share of employment of skill levels 2-4 (med-high) according to the International Standard Classification of Occupations in total employment https://www.ilo.org/public/english/bureau/stat/isco/isco08/index.htm | ILO |
| No. of trade agreement partners (log) | Logarithm of the number of PTA partners | Content of Deep Trade Agreements |
| Depth of PTAs (log) | Logarithm of the number of provisions in deep PTAs as described in Hoffman et al. (2017) | Content of Deep Trade Agreements |
| Time to clear import (log) | Logarithm of the number of days required to import based on the Doing Business 06.16 methodology | Doing Business Database |

Table 6: Variable Definitions and Data Sources
Source: Fernandes et al. (2020), Harmes-Liedtke and Oteiza (2021a) and Harmes-Liedtke and Oteiza (2021b)

| | No. of obs. | Average | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| Summary statistics based on the country averages in the 2010s (from 2010 to 2020) | | | | | |
| Overall GQII score | 103 | 67.47 | 19.73 | 29.44 | 99.41 |
| GQII accreditation score | 103 | 0.711 | 0.204 | 0.232 | 0.997 |
| GQII metrology score | 103 | 0.692 | 0.171 | 0.460 | 0.998 |
| GQII standards score | 103 | 0.622 | 0.248 | 0.149 | 0.996 |
| Backward GVC participation share | 103 | 0.231 | 0.129 | 0.0522 | 0.661 |
| Forward GVC participation share | 103 | 0.203 | 0.0736 | 0.0762 | 0.454 |
| Backward GVC participation level (log) | 103 | 7.990 | 2.466 | 3.175 | 12.70 |
| Forward GVC participation level (log) | 103 | 7.938 | 2.422 | 3.328 | 13.02 |
| Avg. tariff rate (%) | 103 | 5.715 | 4.726 | 0 | 28.33 |
| FDI inflows (log) | 103 | 7.527 | 1.964 | 0.533 | 12.47 |
| Distance to GVC hubs (log) | 103 | 10.04 | 0.288 | 9.553 | 10.68 |
| Domestic industrial capacity (log) | 103 | 22.77 | 2.301 | 17.85 | 28.68 |
| Political stability index | 103 | -0.118 | 0.853 | -2.022 | 1.442 |
| Rents from resources / GDP (%) | 103 | 7.456 | 9.051 | 0.000292 | 42.76 |
| Capital / GDP (log) | 103 | -12.06 | 0.418 | -13.04 | -11.18 |
| Land / GDP (log) | 103 | -12.89 | 2.042 | -19.78 | -7.879 |
| Low skilled labour / GDP (log) | 103 | -18.60 | 1.443 | -22.21 | -14.83 |
| Medium/High skilled labour / GDP (log) | 103 | -16.58 | 1.346 | -19.02 | -13.25 |
| No. of trade agreement partners (log) | 101 | 2.993 | 0.843 | 1.099 | 4.336 |
| Depth of PTAs (log) | 101 | 5.408 | 1.295 | 1.609 | 7.546 |
| Time to clear import (log) | 103 | 22.82 | 15.66 | 4 | 74.67 |

Table 7: Summary Statistics

| | Overall GQII Score | Backward GVC participation share | Forward GVC participation share | Backward GVC participation level (log) | Forward GVC participation level (log) |
|---|---|---|---|---|---|
| Overall GQII Score | 1 | | | | |
| Backward GVC participation share | 0.249* | 1 | | | |
| Forward GVC participation share | 0.00575 | -0.462*** | 1 | | |
| Backward GVC participation level (log) | 0.890*** | 0.342*** | -0.0326 | 1 | |
| Forward GVC participation level (log) | 0.857*** | 0.0610 | 0.227* | 0.947*** | 1 |
| ="* p<0.05 | ** p<0.01 | *** p<0.001" | | | |

Table 8: Correlations between GVC measures and overall GQII score

| | Overall GQII Score | Distance to GVC hubs (log) | Time to clear import (log) | Political stability index | Domestic industrial capacity (log) | Rents from resources / GDP (%) |
|---|---|---|---|---|---|---|
| Overall GQII Score | 1 | | | | | |
| Distance to GVC hubs (log) | -0.254* | 1 | | | | |
| Time to clear import (log) | -0.493*** | 0.201* | 1 | | | |
| Political stability index | 0.216* | -0.0767 | -0.485*** | 1 | | |
| Domestic industrial capacity (log) | 0.891*** | -0.188 | -0.369*** | 0.0605 | 1 | |
| Rents from resources / GDP (%) | -0.285** | 0.164 | 0.412*** | -0.216* | -0.184 | 1 |
| Land / GDP (log) | -0.415*** | 0.262** | 0.591*** | -0.373*** | -0.397*** | 0.386*** |
| Capital / GDP (log) | -0.239* | 0.0713 | 0.263** | -0.316** | -0.218* | 0.0790 |
| Medium/High skilled labour / GDP (log) | -0.573*** | 0.262** | 0.629*** | -0.627*** | -0.540*** | 0.216* |
| Low skilled labour / GDP (log) | -0.502*** | 0.399*** | 0.554*** | -0.626*** | -0.449*** | 0.132 |
| FDI inflows (log) | 0.822*** | -0.138 | -0.398*** | 0.195 | 0.850*** | -0.156 |
| Avg. tariff rate (%) | -0.498*** | 0.254* | 0.362*** | -0.320** | -0.434*** | 0.193 |
| No. of trade agreement partners (log) | 0.294** | -0.513*** | -0.423*** | 0.252* | 0.156 | -0.208* |
| Depth of PTAs (log) | 0.383*** | -0.473*** | -0.456*** | 0.398*** | 0.240* | -0.296** |
| ="* p<0.05 | ** p<0.01 | *** p<0.001" | | | | |

Table 9: Correlations between determinants of GVC participation and overall GQII score

| Land / GDP (log) | Capital / GDP (log) | Medium/High skilled labour / GDP (log) | Low skilled labour / GDP (log) | FDI inflows (log) | Avg. tariff rate (%) | No. of trade agreement partners (log) | Depth of PTAs (log) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| 1 | | | | | | | |
| 0.239* | 1 | | | | | | |
| 0.639*** | 0.430*** | 1 | | | | | |
| 0.570*** | 0.547*** | 0.855*** | 1 | | | | |
| -0.444*** | -0.256** | -0.597*** | -0.491*** | 1 | | | |
| 0.290** | 0.148 | 0.462*** | 0.388*** | -0.384*** | 1 | | |
| -0.262** | -0.00470 | -0.333*** | -0.374*** | 0.0979 | -0.271** | 1 | |
| -0.288** | -0.168 | -0.443*** | -0.448*** | 0.193 | -0.385*** | 0.912*** | 1 |
| | | | | | | | |
| | | | | | | | |

| Backward GVC participation – standardization | | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | Backward GVC participation share | | | | | |
| | | | | | | |
| GQII Standards Score | 0.100* | 0.217** | -0.065 | -0.044 | 0.104 | 0.243* |
| | (0.051) | (0.109) | (0.088) | (0.251) | (0.068) | (0.132) |
| Distance to GVC hubs (log) | | -0.096** | | 0.054 | | -0.105* |
| | | (0.046) | | (0.216) | | (0.057) |
| Time to import (log) | | 0.002 | | 0.000 | | 0.001 |
| | | (0.001) | | (0.003) | | (0.001) |
| Political stability index | | 0.030 | | -0.042 | | 0.027 |
| | | (0.020) | | (0.058) | | (0.025) |
| Domestic industrial capacity (log) | | -0.041*** | | -0.048 | | -0.046*** |
| | | (0.013) | | (0.039) | | (0.015) |
| Rents from resources / GDP (%) | | -0.004*** | | -0.003 | | -0.004* |
| | | (0.001) | | (0.003) | | (0.002) |
| Land / GDP (log) | | -0.018** | | -0.007 | | -0.023** |
| | | (0.007) | | (0.020) | | (0.010) |
| Capital / GDP (log) | | 0.036 | | -0.013 | | 0.080* |
| | | (0.033) | | (0.085) | | (0.041) |
| Medium/High-skilled labour / GDP (log) | | -0.004 | | -0.068** | | 0.022 |
| | | (0.018) | | (0.030) | | (0.042) |
| Low-skilled labour / GDP (log) | | 0.014 | | 0.058 | | -0.007 |
| | | (0.018) | | (0.033) | | (0.030) |
| FDI inflows (log) | | 0.018* | | 0.021 | | 0.027** |
| | | (0.010) | | (0.023) | | (0.013) |
| Avg. tariff rate (%) | | -0.005* | | -0.002 | | -0.005 |
| | | (0.003) | | (0.008) | | (0.003) |
| No. of trade agreement partners (log) | | -0.011 | | -0.046 | | -0.063 |
| | | (0.037) | | (0.100) | | (0.051) |
| Avg. depth of trade agreements (log) | | 0.015 | | 0.043 | | 0.051 |
| | | (0.025) | | (0.058) | | (0.036) |
| | | | | | | |
| Observations | 103 | 101 | 29 | 29 | 74 | 72 |
| R-squared | 0.037 | 0.478 | 0.020 | 0.622 | 0.031 | 0.543 |
| Number of ISO2 | 103 | 101 | 29 | 29 | 74 | 72 |
| Standard errors in parentheses | | | | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | | | | |

Table 10: Backward GVC participation – standardization

| Backward GVC participation – standardization | | | | | |
|---|---|---|---|---|---|
| (7) | (8) | (9) | (10) | (11) | (12) |
| Backward GVC participation level (log) | | | | | |
| | | | | | |
| 8.598*** | 1.399* | 6.749*** | 0.741 | 7.950*** | 1.342 |
| (0.498) | (0.807) | (0.838) | (1.824) | (0.622) | (0.959) |
| | -0.632* | | 1.335 | | -0.489 |
| | (0.341) | | (1.569) | | (0.413) |
| | 0.010 | | -0.012 | | 0.008 |
| | (0.008) | | (0.019) | | (0.010) |
| | 0.248* | | -0.419 | | 0.368* |
| | (0.148) | | (0.418) | | (0.184) |
| | 0.553*** | | 0.427 | | 0.509*** |
| | (0.096) | | (0.284) | | (0.107) |
| | -0.006 | | 0.042* | | -0.013 |
| | (0.010) | | (0.022) | | (0.013) |
| | -0.135** | | 0.033 | | -0.147** |
| | (0.054) | | (0.148) | | (0.072) |
| | 0.316 | | 0.731 | | 0.544* |
| | (0.245) | | (0.619) | | (0.298) |
| | -0.289** | | -0.632** | | -0.044 |
| | (0.135) | | (0.222) | | (0.307) |
| | 0.032 | | 0.031 | | -0.064 |
| | (0.132) | | (0.241) | | (0.215) |
| | 0.202** | | 0.062 | | 0.320*** |
| | (0.078) | | (0.165) | | (0.096) |
| | -0.038* | | -0.000 | | -0.036 |
| | (0.020) | | (0.060) | | (0.023) |
| | 0.162 | | 0.363 | | -0.047 |
| | (0.277) | | (0.731) | | (0.372) |
| | -0.127 | | 0.078 | | 0.072 |
| | (0.183) | | (0.419) | | (0.259) |
| | | | | | |
| 103 | 101 | 29 | 29 | 74 | 72 |
| 0.747 | 0.923 | 0.706 | 0.934 | 0.694 | 0.908 |
| 103 | 101 | 29 | 29 | 74 | 72 |
| | | | | | |
| | | | | | |
| | | | | | |

| | Backward GVC participation – metrology | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | Backward GVC participation share | | | | | |
| | | | | | | |
| GQII Metrology Score | 0.223*** | 0.422*** | 0.069 | 0.255 | 0.211** | 0.385** |
| | (0.071) | (0.125) | (0.154) | (0.236) | (0.092) | (0.178) |
| Distance to GVC hubs (log) | | -0.098** | | -0.015 | | -0.107* |
| | | (0.044) | | (0.212) | | (0.056) |
| Time to import (log) | | 0.001 | | 0.001 | | 0.000 |
| | | (0.001) | | (0.002) | | (0.001) |
| Political stability index | | 0.014 | | -0.036 | | 0.016 |
| | | (0.020) | | (0.053) | | (0.026) |
| Domestic industrial capacity (log) | | -0.045*** | | -0.061* | | -0.044*** |
| | | (0.011) | | (0.033) | | (0.013) |
| Rents from resources / GDP (%) | | -0.003** | | -0.003 | | -0.004* |
| | | (0.001) | | (0.003) | | (0.002) |
| Land / GDP (log) | | -0.019*** | | -0.005 | | -0.018* |
| | | (0.007) | | (0.019) | | (0.010) |
| Capital / GDP (log) | | 0.041 | | -0.033 | | 0.082** |
| | | (0.032) | | (0.078) | | (0.040) |
| Medium/High-skilled labour / GDP (log) | | -0.006 | | -0.070** | | 0.003 |
| | | (0.017) | | (0.029) | | (0.044) |
| Low-skilled labour / GDP (log) | | 0.012 | | 0.061* | | -0.003 |
| | | (0.017) | | (0.032) | | (0.029) |
| FDI inflows (log) | | 0.014 | | 0.021 | | 0.018 |
| | | (0.010) | | (0.022) | | (0.014) |
| Avg. tariff rate (%) | | -0.005* | | -0.001 | | -0.004 |
| | | (0.003) | | (0.008) | | (0.003) |
| No. of trade agreement partners (log) | | 0.001 | | -0.083 | | -0.019 |
| | | (0.035) | | (0.103) | | (0.052) |
| Avg. depth of trade agreements (log) | | 0.009 | | 0.055 | | 0.021 |
| | | (0.024) | | (0.057) | | (0.037) |
| | | | | | | |
| Observations | 103 | 101 | 29 | 29 | 74 | 72 |
| R-squared | 0.088 | 0.518 | 0.007 | 0.650 | 0.068 | 0.552 |
| Number of ISO2 | 103 | 101 | 29 | 29 | 74 | 72 |
| Standard errors in parentheses | | | | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | | | | |

Table 11: Backward GVC participation – metrology

| | | | | | |
|---|---|---|---|---|---|
| Backward GVC participation – metrology | | | | | |
| (7) | (8) | (9) | (10) | (11) | (12) |
| Backward GVC participation level (log) | | | | | |
| | | | | | |
| 12.594*** | 3.656*** | 10.923*** | 3.270* | 11.321*** | 2.914** |
| (0.691) | (0.894) | (1.683) | (1.568) | (0.775) | (1.274) |
| | -0.636** | | 0.651 | | -0.501 |
| | (0.317) | | (1.408) | | (0.402) |
| | 0.006 | | -0.013 | | 0.008 |
| | (0.007) | | (0.016) | | (0.009) |
| | 0.110 | | -0.428 | | 0.279 |
| | (0.142) | | (0.350) | | (0.184) |
| | 0.480*** | | 0.366 | | 0.487*** |
| | (0.079) | | (0.220) | | (0.093) |
| | 0.001 | | 0.050** | | -0.013 |
| | (0.010) | | (0.019) | | (0.013) |
| | -0.144*** | | 0.026 | | -0.122* |
| | (0.051) | | (0.123) | | (0.069) |
| | 0.350 | | 0.624 | | 0.557* |
| | (0.228) | | (0.518) | | (0.290) |
| | -0.326** | | -0.638*** | | -0.227 |
| | (0.126) | | (0.194) | | (0.316) |
| | 0.036 | | 0.056 | | -0.004 |
| | (0.122) | | (0.211) | | (0.211) |
| | 0.156** | | 0.072 | | 0.244** |
| | (0.073) | | (0.145) | | (0.101) |
| | -0.032* | | -0.000 | | -0.036 |
| | (0.018) | | (0.051) | | (0.022) |
| | 0.243 | | -0.131 | | 0.252 |
| | (0.255) | | (0.682) | | (0.369) |
| | -0.172 | | 0.267 | | -0.146 |
| | (0.171) | | (0.377) | | (0.264) |
| | | | | | |
| 103 | 101 | 29 | 29 | 74 | 72 |
| 0.767 | 0.933 | 0.609 | 0.949 | 0.748 | 0.913 |
| 103 | 101 | 29 | 29 | 74 | 72 |
| | | | | | |
| | | | | | |
| | | | | | |

GLOBAL QUALITY INFRASTRUCTURE INDEX

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